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V.37 #10

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OCTOBER 1958

THE INSTITUTION OF

PRODUCTION ENGINEERS JOURNAL

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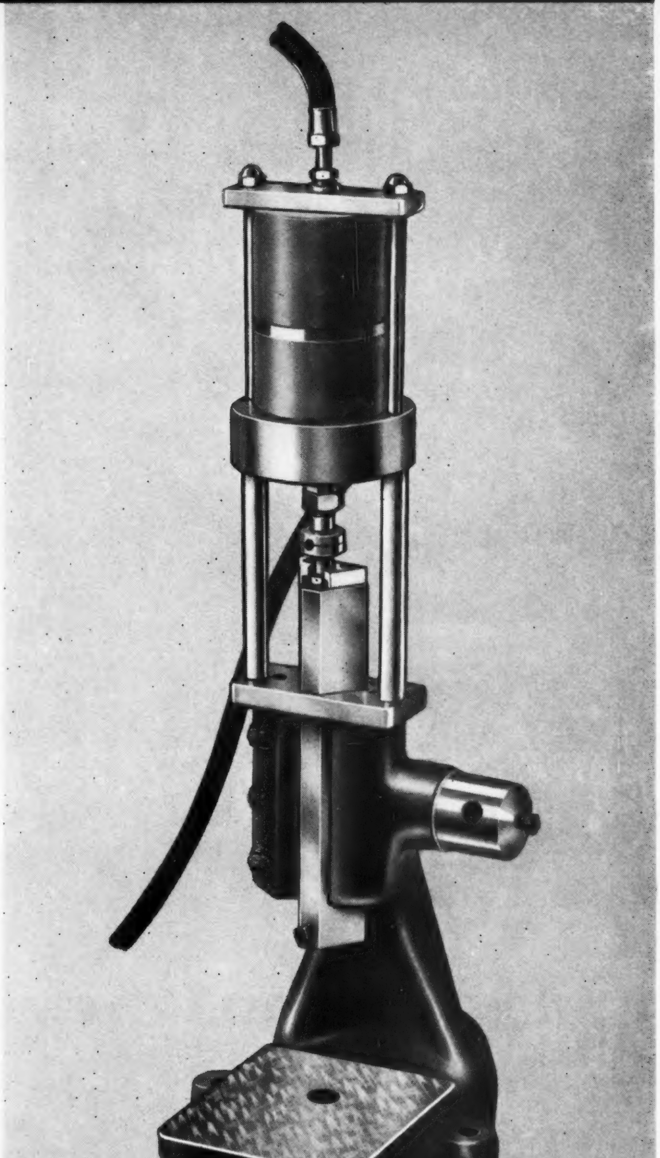

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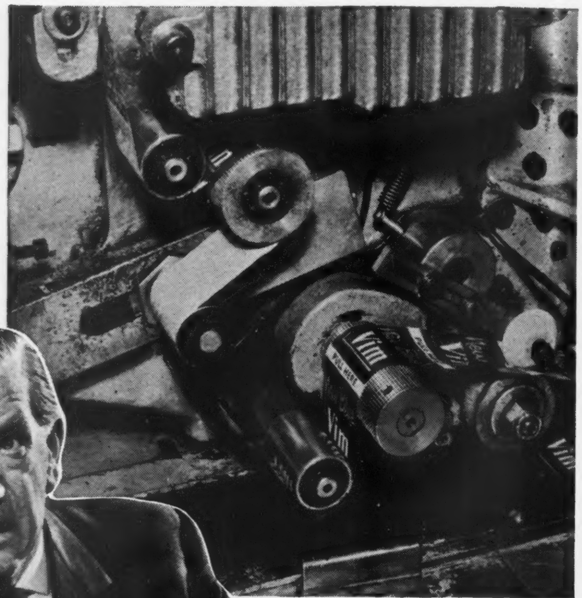

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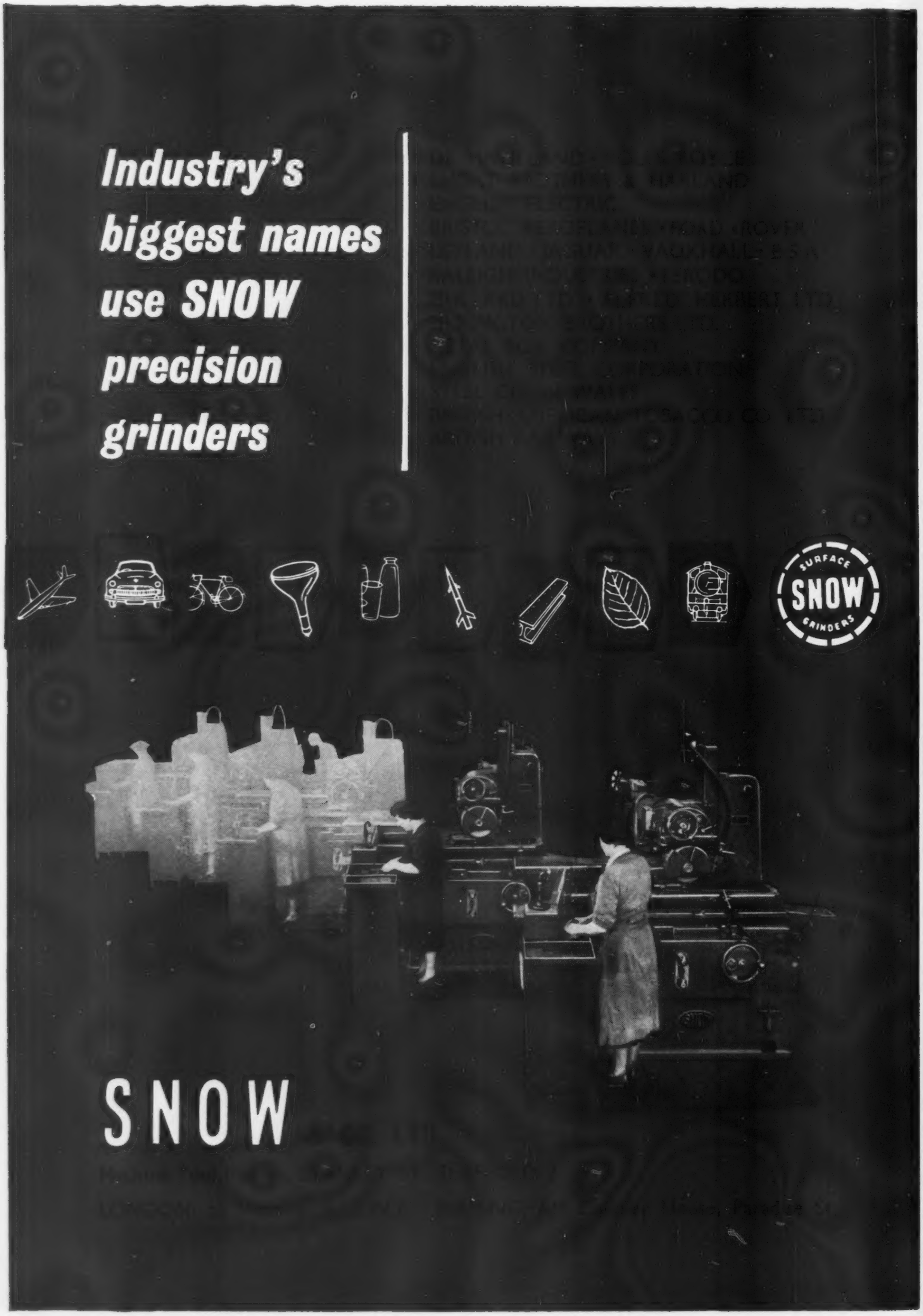
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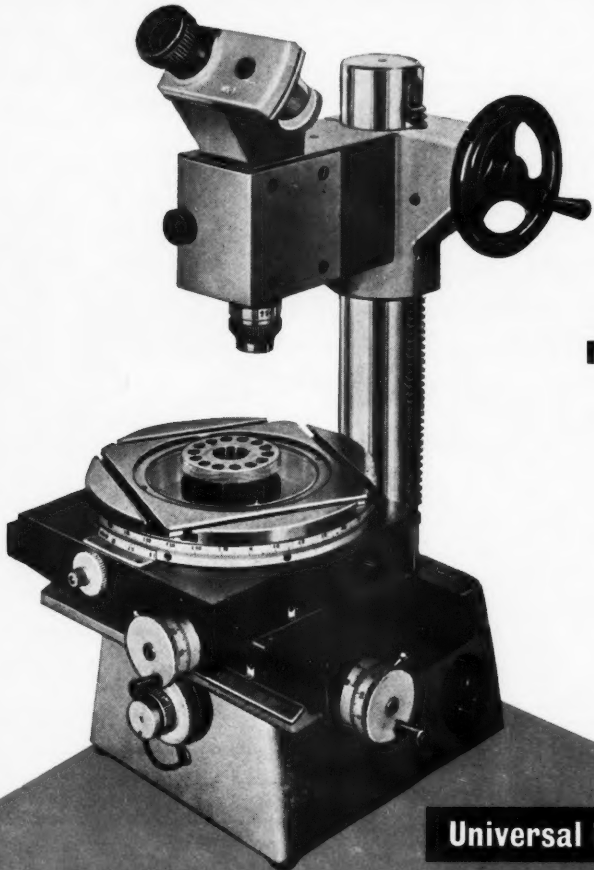

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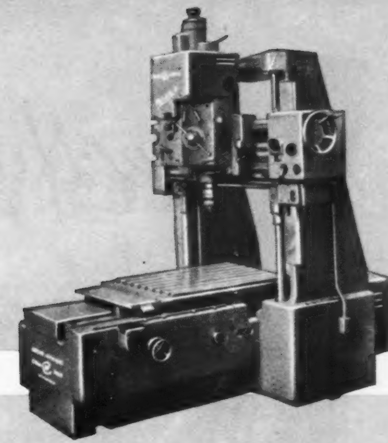

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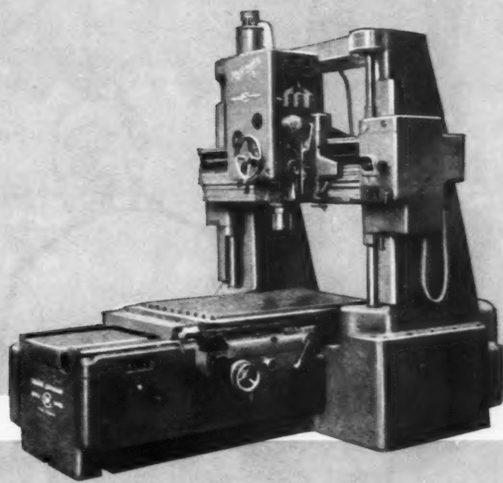

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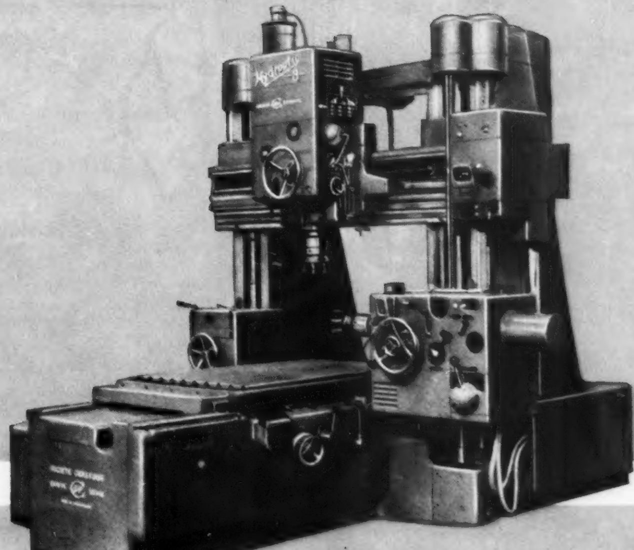

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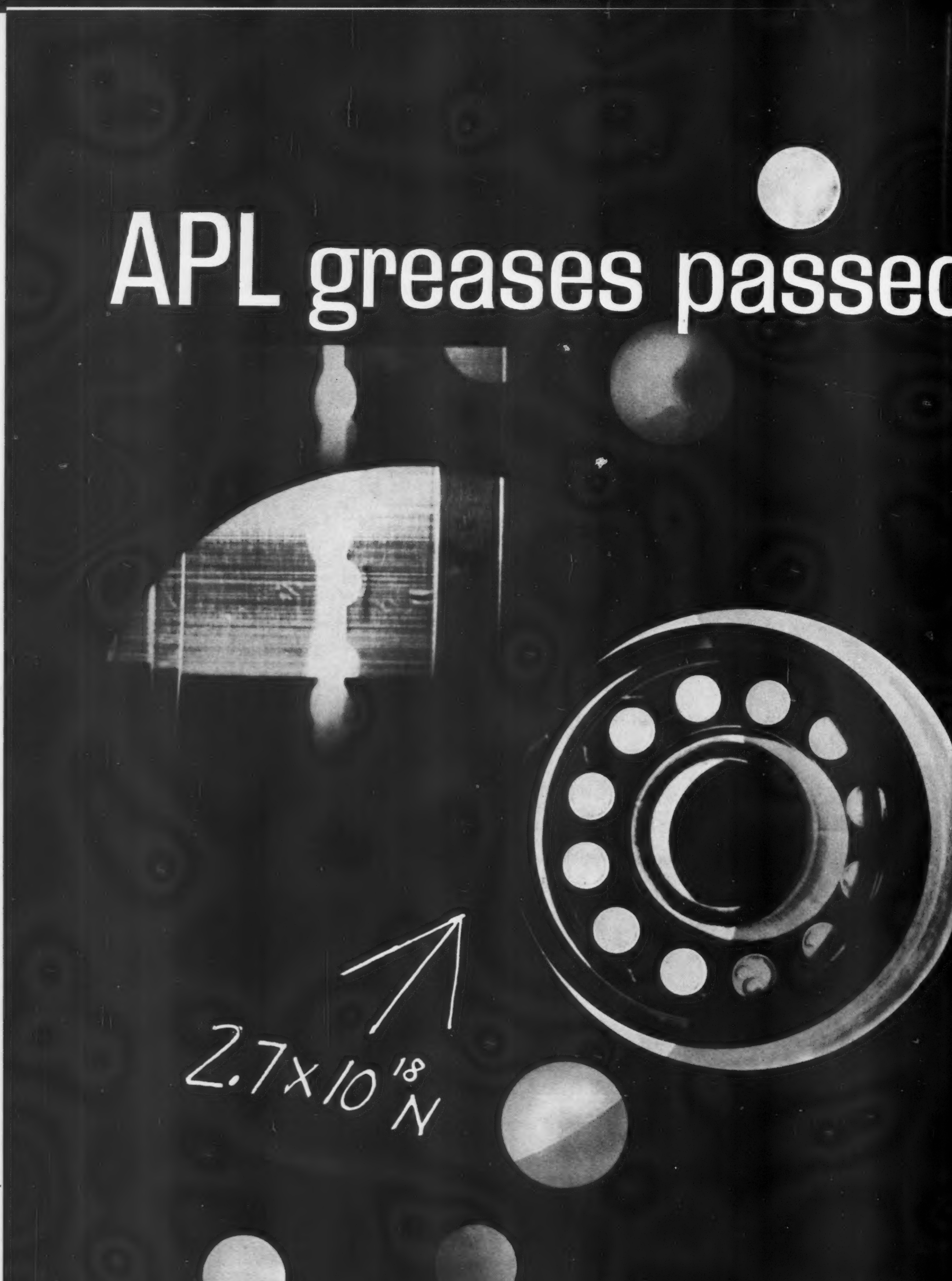

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ed their finals in June...

Radiation broke up the gel structure of conventional greases. They lost their lubricating properties, turned fluid or granulated. Completely new kinds of greases were needed by the atomic power industry for the bearings situated within the radiation field.

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The Research Story

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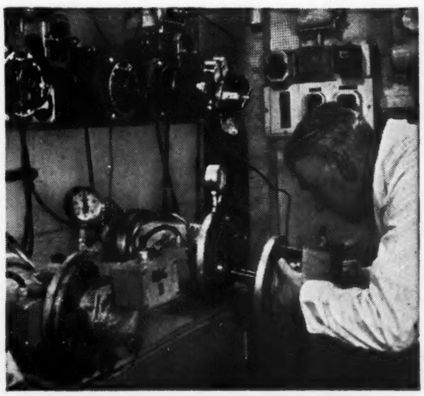

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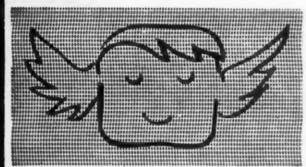

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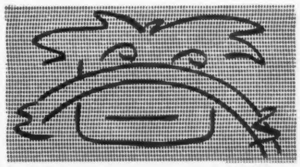

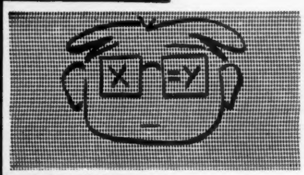

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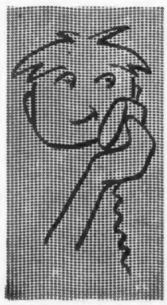

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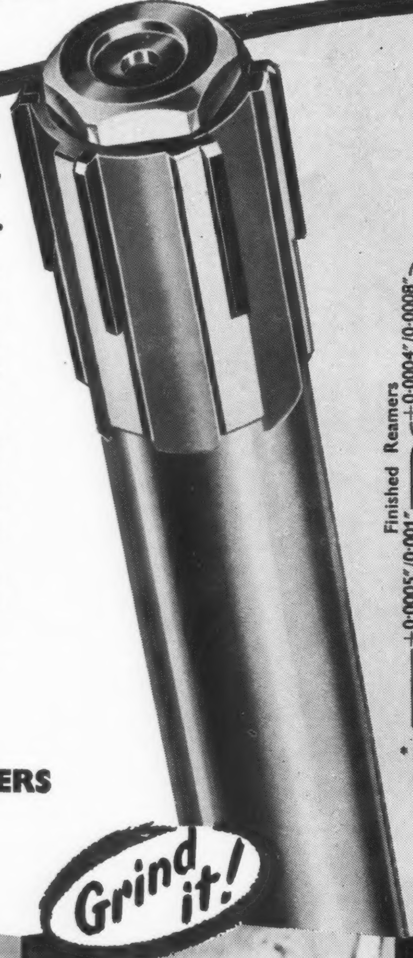

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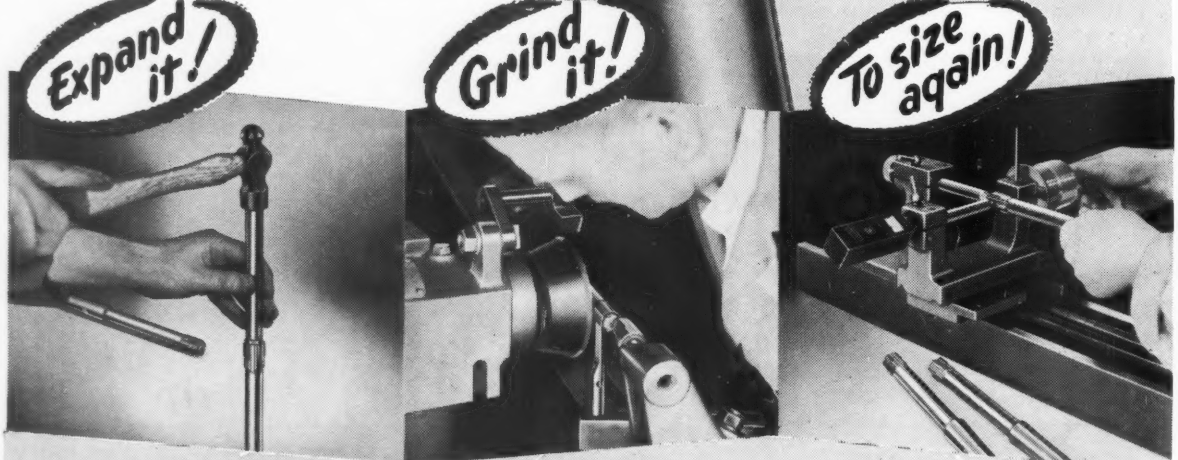

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The Institution of Production Engineers Journal
VOL. 37 No. 10 OCTOBER, 1958

Selling in World Markets

A Report of the opening Session of the Production Conference, held at Olympia last May, at which this vitally important subject was discussed by representatives of the Federation of British Industries, the Board of Trade, and the buying and selling industries.

The Chairman was Major-General K. C. Appleyard, C.B.E., T.D., D.L., J.P., M.I.Mech.E., M.I.Prod.E., a Past President of the Institution, and an internationally known consultant engineer.

OPENING the meeting, the CHAIRMAN, Major-General K. C. Appleyard, C.B.E., T.D., said he thought it was clear to most people that production was of no use at all without sales. The sales people were therefore the spearhead of all our industrial enterprise and efforts.

The sales people themselves had to look back to the production people for designs and specifications to meet particular markets, for deliveries and prices to meet competition, and therefore there was bound to be — or ought to be — a very close alliance between the people who were responsible for selling and the people who were responsible for production.

In the U.K. there had been for many years a seller's market, and far too large a percentage of firms had been too busy, or imagined themselves to be too busy, to worry about going into the export field. But that day, in the Chairman's opinion, had gone, and today the U.K. either went out into the world to sell goods in competition with Germany and Japan and the United States and Russia, or else sank back into conditions of unemployment.

This, therefore, was one of the most important subjects that could be considered at this time; and having this in mind, the Institution had invited four distinguished men who would speak on this problem from their own experience and point of view, and would then discuss amongst themselves some of the points that had arisen. The Chairman hoped they would disagree, because disagreement sometimes provided a good deal more by way of illumination than complete agreement. Subsequently, the discussion would be thrown open to the audience.

Nobody knew better than the Chairman the difficulties of the production engineer who was asked to disturb his standards of production to provide special materials for a special market, and this kind of problem was one that it was hoped would be brought out in the discussion.

The first speaker would be Mr. Thomas Whittaker. He was well-known not only as a fine salesman, but as a man who had his own ideas and was not afraid to express them.

The next speaker would be Dr. E. H. Hague, who also had a mind and definite ideas of his own, and the Chairman was perfectly certain that he would express them. He had had worldwide experience and today was responsible for buying materials in the United Kingdom for the Shell Petroleum Company. These materials ran all the way from garments to large-scale engineering products, and the materials he bought went to over 100 countries.

Following that, they would hear from Sir John Taylor. The Chairman first met Sir John Taylor when he was Britain's Commercial Minister in Washington, an appointment that he filled with great distinction. He enjoyed also meeting him later on when he was the British Ambassador in Mexico. Sir John had seen our efforts from the other side of the world, and the Chairman was personally delighted to see him present as Director General of the Hispanic and Luso-Brazilian Councils. He carried a position of great responsibility with regard to U.K. relations with the Spanish-speaking countries in America.

Finally, Mr. Hughes would address the meeting. Mr. Hughes was one of those delightful and intelligent people who are members of the Civil Service. He was Under-Secretary at the Board of Trade. He had had a wide experience of European and other countries overseas, and he was now in charge of The General Division, concerned with general economic questions, which was a wide subject, the balance of payments, export policy and promotion, and publicity.

This photograph taken at the Production Conference prior to the opening of the Session on "Selling in World Markets" includes the Chairman, General Appleyard, with the speakers. Reading from right: Mr. Thomas Whittaker; Mr. Griffiths, Director of The Incorporated Sales Managers Association; Mr. J. R. Blinch, Secretary of The Purchasing Officers Association; Sir John Taylor; Dr. Hague; General Appleyard; Mr. William Hughes; Mr. W. F. S. Woodford, Secretary of the Institution; and Mr. S. Caselton, Deputy Secretary.

1. THE SALESMAN

Mr. Thomas Whittaker, Managing Director, Smith & Nephew, Ltd.

I DID not quite know what I was coming to when I was invited here. I thought I should be Daniel amongst the lions as a sales manager amongst production people. Nothing pleased me more than to find that I was billed in the programme as a salesman. That is a word which is generally used in the English tongue, I think, with a certain amount of opprobrium. The salesman is looked upon as the sort of chap who goes round telling tall stories and somehow or other forcing upon people goods they don't want to buy at a price they certainly think is far too high. But frankly I feel rather flattered, if I may say so, that you should describe me as a salesman, because I make no bones about it that I think selling is a business activity which has a more fundamental influence on the life and the living standards and the economics of the country than any other single activity.

The sales function is very much, in my view, interlinked with the function of producing, and too much play has in the past been given to the treatment of both as distinctive and separate occupations.

We have a saying in our Sales Managers' Association that no business activity starts until something is sold. You may think that is very provocative, but think about it: there is a good deal of truth in it.

It is equally true, of course, that you cannot sell anything unless you can make it, and it does not matter whether you put the chicken first or the egg, in this case. There is undoubtedly a strong interlink between the function of producing goods and the function of disposing of them. Both are completely interdependent and no more so than in the field of overseas selling.

fitting production to sales

I should like to spend a few minutes upon a subject General Appleyard has referred to generally: namely, what one might call the fitting of production to sales. It has several aspects, and the most common and one of the most difficult, perhaps, in regard to selling goods overseas relates to the type of article that should be sold.

The development of economic production is surely based very largely upon rigidity. You people, if I understand correctly, very much like to design machines that will turn out incredible numbers per minute, or per hour, or per day, or per week, with three shifts. You like them to run 24 hours a day. You would obviously like, having spent a lot of time and effort in designing such plant, to be able one fine morning to press the button, so to speak, and just stand by and see it go beautifully and smoothly, turning off the goods at the other end. Everything is mechanical; very little labour is used; and there is nothing else to worry about.

It is excellent from your point of view, but what about selling ? Most selling is in fact based not upon rigidity but upon elasticity, viability, call it what you will — the ability to move quickly from one set of circumstances to another. Whereas *you* are dealing very largely with sheer hard facts and make mathematical calculations which show that if you can produce x per minute, you can get a certain definite mathematical result. We do not deal in facts as much. We deal in people's lives, and thoughts, and whims and fancies. Therefore, although a lot has been written and spoken about the ability to turn selling into an exact science, it cannot and never will be an exact science. You just cannot predict what the consumer — and I am thinking just now very largely in terms of the mass consumer, the great wide public all over the world — will think; you just cannot quite predict how they will regard an article from the point of view of colour, from the point of view of what it will do for them. I think we should remember in this connection that the difference in outlook is emphasised also by the fact that production turns very largely upon how you make an article, what goes into it, what are the qualities of the materials that go into it, and so on. On the other hand, the purpose for which it really sells has not very much to do with what goes into it. It has much more to do with how it will perform and whether what it will do for the purchaser, the consumer, is worth the money that he is asked to pay for it.

This difference becomes very marked in regard to overseas business and it is no good pretending that you can, of necessity, because a certain article is the one that you produce and can produce most economically, say that it is the one the consumer wants. The consumer may want rounded corners. You may say it must be square because otherwise there is a loss of material, a wastage factor. You may say you cannot do it with round corners; that like Henry Ford you can produce it in any colour they like, provided it is black. I'm sorry, but the lady in the Argentine or the South of France might very well like it in pink. She may like it in pink with a white edge. She may like it with all sorts of fancy trims. And she is the person on whom you and the salesman and everybody concerned with the operation depends.

We sales people are accused of asking you too often to do the impossible. You then tell us that if we must have the article with rounded corners and two or three colours instead of in its simplest form, it will cost us 200% more. The 200% is so flagrant an exaggeration that we won't dwell on that one. But what is the good of producing the article to your standards — that is to say, without the trimmings the good lady purchaser or the man purchaser wishes to have — if you cannot sell it and if they do not want it ? A wonderful machine that will turn out vast quantities of articles that nobody wants is no good to anybody.

meeting the customer's needs

There are other aspects of co-operation. You accuse your sales people, of course, of never knowing what they want, of never giving you a decent run in many cases. When we ask what you mean by a decent run, it usually turns out to be starting the machine on 1st January and letting it run on the same article, the same colour, the same size, the same everything, and the same packaging to the 31st December. We may want to sell by a variety of units, one customer wanting 50, another 100 and another something else. All these things are frequently vital to securing a market, and they are more necessary than when you are pioneering business.

Let me give you an example. We may perhaps, particularly in overseas markets, have someone coming along and requiring us to supply something different from the standard in one particular or another or perhaps even a completely new article in quite small quantities in a market that is just starting. The size of the business we can offer you does not compare with the mammoth quantities you make in your established lines and you do not want to produce it. This is one of the root causes, I think, why we fail. Between us, you as production people and we as sales people, we fail to get ourselves into the right frame of mind where you can say : " Well, all right. We recognise it. We have to do it, but it hurts ". We equally — and I will admit this — might sometimes make a little more of a contribution towards solving your sort of problem.

I well remember in our own business some years ago the time when we were very short of supplies based to a great extent on textiles. The day came when we got all the cotton cloth we wanted. It was not long afterwards, quite frankly, that our production manager came to us and said : " I have given you a pretty rough ride these last years, because I haven't been able to do many of the things you wanted. I am going to let you have these things now. You must have them, I recognise, to open new markets, to develop new products, and so on ".

There are many aspects of this problem, but I believe it is fundamentally at the root of some of the failures for which mainly British industry generally, but the sales people in particular, are blamed. I hope we can do something this afternoon, in our discussion, to get a better appraisal of each other's problem and a better working alliance between production and sales. If we can do that, it will be both useful and helpful.

Just let me give a final illustration of the point. Many years ago, before the War, I was concerned for a brief period in a business making motor-cycles. We had an order — a trial order for a foreign army — which we executed successfully to specification, colours and so on. We then got a larger order for several hundred machines. Being relatively new, I passed this over to the factory side and told them there was a specification. They knew the specification already and they could get on with the machines. Later on, in the works, I was invited to look at the first delivery. I looked at the machines and immediately said : " I'm sorry, but that's not the colour. This doesn't tally with the description of the green finish and the dull exhaust pipes and the rest as given in the specification ". I was told : " But it's perfectly all right ", but I insisted and they went away and came back saying they had looked at the specification and they were perfectly happy about it. I rather unwillingly let the machines go, but no sooner had they arrived than a cable came saying that the first batch of machines was wrong.

the reason why

It took several days to locate the specification. Production engineers know better than I do where specifications get to. We found it with the old foreman in the paint shop, together with the specimen. We had only to take one look at it to find the answer. Instead of using the colour specified, they had finished the machines with the British Army colour. " Well ", said the foreman, " why not ? If it's good enough for the British Army it's damn well good enough for any other army ! "

2. THE BUYER

Dr. E. H. Hague, Head of Purchasing Department, Shell Petroleum Company, Ltd.

MY comments on this subject — quite general ones, since time does not permit more — are made from the buyer's viewpoint based on an operation involving exporting British equipment and materials to over 100 countries. If, on occasion, I appear to be trying to "teach my grandmother to suck eggs" forgive me — it is not intended. My hope is simply that one or two of the points touched on may be helpful by the very fact that the overall problem is approached from a quite different angle from that of the manufacturer and salesman.

I. Delivery Problems

Delivery problems include three major "needs", as I see it:

1. *the need to maintain delivery promises*

A safe premise — from the supplier's viewpoint — would be that the overseas buyer wants his materials delivered in good time and is not interested in reasons why this cannot be done.

However, it is good to be able to report that in recent years there has been a marked improvement in the delivery performance of British suppliers. Whereas in 1949 we could only expect 10 of 20 orders to be delivered on time, in 1958 we can expect 16 out of 20 to be on time.

2. *the need for short deliveries*

On occasion, the supplier considers quite abnormal the potential overseas customer who just cannot accept the deliveries he offers. He may urge his customers to look further ahead than they are willing to do in the assessment of their firm demands. Why should they do this if they can get what they want elsewhere with shorter deliveries ?

Perhaps more than half the suppliers' problems arising from cancellations, deferments and modifications would not arise if short deliveries were possible.

The important point is that British suppliers should know—and be able to match realistically—deliveries quoted by their competitors in other parts of the world.

3. *the need to advise customers when delayed deliveries are unavoidable*

Most suppliers do not give this service — they await expediting action by their customers. Surely it must be assumed that all overseas customers are not ready and willing — nor even able — to take the sort of expediting action we do.

Should not the nettle be grasped early and firmly and this service given to customers ?

II. Quality and Quality Control

There is evidence that the standard of British workmanship is higher now than it was 20 or even 10 years ago. Regrettably, all too often the record is marred — sometimes by lack of adequate production control and inspection by the manufacturer — sometimes because of reliance on the skill of one man whose absence endangers control.

To minimise the risk of sending unsatisfactory materials overseas the buyer may set on his own inspection. Quite wrongly, some suppliers consider that this relieves them of their responsibility for ensuring good workmanship and sound quality.

A supplier may himself prefer to set on a responsible independent inspection service — eg., Lloyd's — and to incorporate the cost of this in his prices. The wider application of this procedure merits consideration.

In America there are such devices as the "A.P.I. Monogram" and in South Africa the mark of the South African Bureau of Standards, indicative of sound production methods and reasonable assurance of good quality products. Here we have tried — with admittedly comparatively little success so far — to promote a wide use of the Kite Mark. There are now, however, some signs of promising developments.

III. Prices

Obviously these and the terms of payment must be attractive to the overseas buyer — whose ultimate yardstick of price comparison is, it should be remembered, landed costs.

Some suppliers in other countries appear to "play tunes" with their prices, depending upon whether they want a particular order — usually — but not always — associated with the conditions of their order books.

The impact of price-fixing arrangements in Britain is not easy to assess, but there are important cases where "ring" prices are quite unattractive compared with those of good quality Continental products.

Perhaps increased attention should be given to the cost of spare parts, both ex-works and the "marked up" prices of spares available overseas. It is — or should be — an important factor in the buyer's selection of equipment, and it is interesting to note the wide variation which occurs if equipment from different suppliers is costed from the individual prices of its component parts.

IV. Packaging and Preservation

In recent years there has been considerable improvement in the "protection" and packaging of materials for export. However, some suppliers still tend to underestimate the rough handling and extreme climatic conditions which packages must withstand on so many of their journeys to destinations overseas.

Despite the improvement, we still find it necessary to maintain a small advisory unit to tackle this problem with our suppliers.

V. Design

We have a great deal "on the ball" in inventive ability. Our weakness seems to be an unreadiness to find out exactly what the user would like to have, not only from a purely utilitarian viewpoint but also from the viewpoint of appearance and finish.

Here are six questions — on each of which a book could be written:

(a) Do we tend to start too many hares and bring home too few ?

(b) As a development of this, are there not some lines in which a combined attack by a group of suppliers might be worthwhile ? An example of this might well be found in the field of industrial gas turbines.

(c) Do we not tend at times to design for an unnecessarily long life with an associated price disadvantage in comparison with our competitors ?

(d) Do we recognise fully that a new development — even if based on a simple design — seldom, if ever, gets away without its "snags" ? As a corollary, do we ensure that such "snags" are found and cleared before equipment is sent overseas ?

(e) Do our design people pay adequate attention to the products of their competitors — home and overseas — particularly when entering a new field ?

(f) Should we not encourage increased development of "gimmicks" — a fascinating field in which the Americans are so outstanding and the Australians and Germans are good ?

VI. Market Research

In one form or another market research is a continuous operation — not essentially a "one timer", as many seem to think. It embraces quality and design which are ever liable to change — as well as size of potential markets. Regular visits overseas are a "must" to determine user "likes" and "preferences", to estimate sales potential and to "size up" the competition.

There is a need for increasing numbers of men — senior, technical, open-minded and ready to talk at all levels and to listen to the users or potential users of British equipment and materials.

VII. Sales Problems

pre-sales

Salesmanship — the ability to sell a product which the salesman knows will fill the needs of his customers so that further sales will almost naturally follow — has not been a strong point of British suppliers in post-War years. There are, of course, brilliant exceptions to this generalisation.

It is recognised that in a seller's market, particularly with an overall shortage of skilled, experienced men, good men tend to be used nearer the production line. The comparatively "easy" home market has encouraged this.

The most useful type of salesman is one who is familiar not only with the details of his products and those of his competitors worldwide, but with the specific uses to which the customer intends to put them.

Four brief points:

(a) The need for timely submission of quotations and for intelligent "follow-up" work.

(b) The need for catalogues and such things as service manuals to be clear, informative and available in the language of the potential customer.

(c) The need for advices on modifications in design and on new designs and forward planning to be given regularly to important customers and to potential customers.

(d) The help which can be provided by good London representation — and the difficulty of finding the right men.

post-sales

After-sales service at home and abroad is a keystone to success in the export business. The overseas representation must be sound and active.

The handling of complaints on equipment and materials supplied from the United Kingdom is now a great deal better than it was some years ago.

VII. Spare Parts Policies

In early post-War years the production of spare parts was the Cinderella of British industry. It seemed much more important to sell another engine, pump or compressor than to ensure that those already sold were not shut down for lack of spares. In recent years, the concept of unraidable spares production lines has spread widely and service is very much better than it was. That is not to say there is no room for improvement.

"Rationalisation" of designs, for example of diesel and petrol engines, has considerably simplified the ordering/stocking position of spare parts, but wherever suppliers' representatives are not functioning overseas as spares stockists, probably the greatest single problem of the overseas user is the stocking of parts. The risks of overstocking and obsolescence are great— and to some extent well-nigh unavoidable. Perhaps increased use should be made of airfreighting — particularly of insurance spares — and suppliers should be expected to make this service available to the overseas customer.

IX. Long-Term Factors

Long-term factors include:

1. *standardisation*

If the imagined ogre of standardisation hampering development and improvement of design can be expelled from suppliers' minds and replaced by the concept that standardisation, such as we have in mind, is a "floor on which to build and not a ceiling", it would be a great step forward for British industry.

Much is being done, at least to establish common essential dimensions, but still how many different types of domestic electric plugs, how many types of electric items on cars, how many different types of valves and cocks there are, to mention but a few.

The metric v. inch/pounds fight is on and it looks as if we here must work in both for years to come.

2. *co-ordination/co-operation*

Surely there is room for increased co-operation and co-ordination in industry in the interests of our vital export business? Particularly does this seem desirable where the cake of demand is just not big enough to satisfy profitably the numerous partakers.

Opportunities for co-ordination of effort do exist in greater or lesser degree within the many "associations", but these do not seem to be used to anything like full extent. In the design field and in the associated research and development work are surely opportunities for increased co-operation between companies, aimed toward maximum useful application of our quite limited resources by reducing duplication of effort on some common problems.

3. *overseas developments*

In an ever-growing number of countries, the installation of assembly plants, followed by full manufacture, appears to be the only sure way to obtain — maintain — or expand — British participation in meeting overseas needs for equipment and materials. The "snags" are manifold, as for example in India, but surely ways and means must be found; if we don't, others will.

X. Inducements to Export

Reference was made some time ago in *The Economist* to the "carrot" and to the "stick" as two forms of inducement. There is a third form which we wish to avoid as the plague — unemployment or fear of unemployment. In some way or other we must surely produce a really attractive "carrot". Both Government and industry are involved, but some of the possible measures would admittedly be "unpopular" politically.

Shortages of foreign currencies, providing as they still do a protective umbrella over large sections of industry, can act as an inducement to the development of quality production and good service so that competition from overseas may then be confidently met regardless of currency controls.

XI. The Smaller Supplier

Many of the smaller suppliers are not set up to tackle readily the mass of controls, paper-work, payment problems, special preservation and packaging conditions and so on, unavoidable in the export business of today. Surely there is much that can, and should, be done to make it possible for many such suppliers to share in our export business to a much greater extent than they do at present.

XII. Buyer/Supplier

Finally, I am quite sure that there is ample opportunity for increased collaboration between buyer and supplier to allow the problems of each to be ventilated and solutions sought which will be helpful to both parties and to our efforts to sell in world markets.

3. THE FEDERATION OF BRITISH INDUSTRIES

Sir John Taylor, K.B.E., C.M.G., Director General, Hispanic and Luso-Brazilian Councils

MY respect for production engineers dates back to the time when I first saw one in action about 10 years ago. He was on a business trip to the Western hemisphere, and in those days the allocation of foreign exchange to business men for business trips abroad was even more tightly controlled than it is today. You had to estimate how long you would stay in each country in order to obtain a specific allowance for that country.

This production engineer was in Argentina, and negotiations for a big contract were going very well; but his supply of local currency was running short. So he sent a telegram to the representative of his bank in New York and told him to transfer some money from his dollar credit for the United States to Buenos Aires. That could not be decided on the spot. It had to be referred to London, and back came the head office in London with a telegram

to this production engineer, saying: "Bank of England want to know why you want to stay another three weeks in Buenos Aires and what you are spending your money on?" Very inquisitive, wasn't it! That put this production engineer on his mettle and he telegraphed back that he needed the extra three weeks to conclude an important contract. As to his expenditure, this was mainly on wine, women and night clubs; and if confirmation of this were required reference could be made to His Majesty's Ambassador (quoting his name), who — he said — joined him in those pursuits. Needless to say, this ensured immediately a smooth flow in the production line of foreign exchange allocations. Who was this paragon of production engineers? None other than General Appleyard!

where to sell

As the Chairman has said, Great Britain is now in a better position to do more business overseas, and we need an expansion of overseas trade for our own economic development. In our discussion on selling in world markets the first thing to decide is where we want to sell. Are we to go for an expansion to our traditional markets, or should we try to enter new ones? Probably both in the case of many exporters.

At present, roughly half our total exports go to the Commonwealth and a quarter to Western Europe. But the pattern of trade, both in commodities in international trade and in trading partners, is constantly changing. Anyhow, it is only common sense to spread the risk in many markets and to be selective. I put it to you as production engineers that we should put the emphasis on *building markets* which will be long-term trading partners, rather than on ones for immediate sales with no continuing contact with that market.

What, then, should we look for in choosing the overseas markets which are most worthwhile?

Obviously you must have information on the size of the market, its purchasing power, its rate of development and its needs, whether its economy is complementary to ours or competitive. Then I think we ought also to give some weight to the general climate of opinion. Can the people in that country be counted on to be friendly and well disposed, or is there any fundamental antagonism in a particular area?

If we can avoid it, we do not want to be too involved in an area where our trade is liable to have interruptions, as with the Middle East oil pipe-lines today.

a major market

I suggest that we should devote more attention than we have been able to do recently to one of the major world markets — Latin America. At the present time, it takes only 5% of our total exports, but in 1913 it took nearly double that percentage, and it may well reach the same level again and exceed it.

The population of the 20 independent republics which constitute Latin America is around 180 million, and the annual rate of growth of the population is high. It is estimated that by the end of this century Latin America will have more than twice the population of the United States and Canada combined. But, of course, unless this increase in population is accompanied by a rise in the standard of living it is not a measure of the potential market. For markets are people with purchasing power, people with money to spend.

Fortunately, the growth of population in Latin America *is* being matched with a proportionately bigger increase, both in the gross national product and in *per capita* income. Latin America, in fact, is one of the fastest growing markets in the world. Our economies are complementary. *They* are important to us as the source of supply of many of our requirements in foodstuffs, industrial materials and oil. *We* are important to them, particularly, as a provider of the capital equipment and the "know-how" they need for their development. We can both provide expanding markets for each other, and 14 of those countries are in the dollar account area. The Latin American countries all have European traditions and are part of our free world. They want closer ties with us, and we in this country enjoy their special sympathy for the part we played in the achievement and maintenance of their independence and for our contribution to their progress in the past.

What, then, are the markets in Latin America? They vary widely. Some countries are very dependent on a single commodity to provide the foreign exchange to pay for their imports. For example, Brazil depends on coffee and Chile on copper. Others have a much more diversified foreign economy and pattern of foreign trade. Some have balance of payments difficulties and restrict remittances abroad and imports. In others there are no exchange difficulties. So within the area, as in world markets generally, it is necessary to be selective.

consumer and industrial markets

There are two kinds of markets — consumer and industrial markets. Consumer markets consist of families, households and individuals who buy for their own consumption. Industrial markets consist of factories, mines, public utilities, Governments and all organisations which buy goods to be used for the production of other goods and services.

In recent years, Latin America has offered an increasing industrial market, but there is no doubt that the new industries in Latin America are providing more well-paid employment and creating a new and growing urban middle-class market with a demand for a new variety of consumer goods.

There are no hard-and-fast rules to follow in going out for the industrial market. Of course, we want to keep our own chimneys smoking, but in some countries, such as Brazil, which protects its local industries by a ban on imports of goods similar to those being manufactured locally, you have to establish a branch factory or see your exports disappear.

Another favourite method for getting established in industry locally is to sell the "know-how" for shares in the local company, or to give technical assistance in return for a royalty. There are often great advantages in having local partners.

Naturally, these markets are very competitive. Our main competitors are the United States of America and Germany. A great deal of the possible business in Latin America, particularly in capital goods, is on deferred credit terms, and the present tendency is for the length of credit demanded to get longer. Realistic and competitive credit terms are just as important in selling as having the right goods at the right price at the right time. And as we have now moved from a seller's to a buyer's market, our exporters need to be in a position to compete effectively on credit terms. I have no doubt from the recent Government pronouncement that this is now well understood in this country.

4. THE BOARD OF TRADE

Mr William Hughes, C.B., Under-Secretary, The General Division, Board of Trade

TO me, as an outsider, the internecine arguments between the production engineers and the salesmen, of which Mr. Whittaker gave us a glimpse just now, are very fascinating. I think the Government cannot begin to help until those arguments have been sorted out within the privacy of your own board rooms.

I want to say something about the help that the Government can give to those who sell in world markets. But I should like first to say a word about one form of help that the Government cannot give and that, I hope, is not one of the inducements which Dr. Hague mentioned.

We in this country have set our faces against any export subsidy or discrimination in favour of exports by the manipulation of taxation and other direct or indirect methods of subsidising. We have done this, not for doctrinaire reasons, but because as one of the biggest exporting countries in the world we do not believe that it would pay us to add this extra burden to our economy.

We need to earn as much as we can from our exports, and we believe world trade will prosper best if others take the same view. We have had a good deal of success in international organisations such as the GATT and the O.E.E.C. in persuading other countries to support this way of thinking.

help for exporters

But there are many ways in which the Government does help exporters to sell, for example, by the commercial negotiations which are going on almost continuously with Commonwealth and foreign Governments, by official participation in overseas trade fairs, very often jointly with trade associations, and by publicity on commercial subjects through the information services overseas.

These are relatively indirect methods of help, and I want to say a few words about two important ways in which the Government can provide direct help to the British exporter through the services offered by the Export Credits Guarantee Department and the Export Services Branch of the Board of Trade.

The Export Credits Guarantee Department — I will call it E.C.G.D. — has the function of providing insurance for United Kingdom manufacturers and merchants against the main risks of financial loss in their overseas trade. The Department covers the commercial risk, the credit-worthiness of the buyer, and the economic or political risks, such things as exchange blockages and licensing restrictions suddenly imposed.

E.C.G.D. business has been built up largely through covering exports on cash or short-term credit up to six months, but an increasing part of its business is now concerned with exports sold on longer terms — the durables and quasi-capital goods of an engineering kind, which are sold on a basis of up to three years' maximum credit, and the real major capital goods products where the credit may go up to five years from the time of shipment. These are becoming increasingly important in the business covered by the Department.

E.C.G.D. does not itself provide finance, but its cover plays an important part in bringing forward finance. Its normal policies are widely accepted by banks as collateral security, and in the capital goods field where financing raises the most difficult problems, E.C.G.D. can often give a direct guarantee to the financing bank in respect of 90% of the total price. An extension of this last facility, the direct bank guarantee, was announced in the budget debate by the President of the Board of Trade.

The terms on which E.C.G.D. will cover business are based on a worldwide network of commercial informants, who report on the credit-worthiness of overseas buyers, and on economic and political reports which are received from Her Majesty's representatives all over the world. This forms a system of credit management whose cost is shared between over 4,000 E.C.G.D. policy holders.

Although the E.C.G.D. does not aim to make a profit, there is no element of subsidy in its services, and at the moment it has an underwriting reserve of some £13 million. But that represents only about 3% of the current liabilities, so you can see the margin is pretty fine. Nevertheless, the Department

has been able to reduce the average premium rate for short-term business from 11s. 7d. per £100 in 1950 - 1951 **to less than 9s.** now, and the total volume of their business has multiplied by about 15 times since the War. So much for E.C.G.D.

Export Services Branch

The other section of the Board of Trade which I want to mention is the Export Services Branch, which is known as E.S.B. for short, with which are associated the commercial diplomatic services in foreign countries and the trade commissioner services in Commonwealth countries.

Its main function is to give assistance, usually free, to United Kingdom exporters to help them to answer some of the questions about markets into which they are thinking of going, of the kind which Sir John Taylor was speaking about.

The principal ways in which the Department does this are the following. Market information is available to anybody on demand. We can produce a great deal of information about market prospects and business conditions and trading methods in most countries. If it is not available in London, special enquiries are made through our representatives in the countries concerned. Information about tariff changes, import restrictions and so on is recorded in London and our records are kept up to date. We can give information on all such matters and on quotas, certificates of origin and all the documentation which earlier speakers have mentioned, or we can find out about it quickly if our records do not show what is wanted.

We can undertake a very useful service, I think, in helping British exporters to find suitable agents or representatives overseas. The Branch does not pick names off lists of potential agents. It gets from the United Kingdom exporter a detailed brief which is sent out to the commercial representative in the country in question and this enables him to do a tailor-made job. Overseas officers do not make recommendations without having personally satisfied themselves about the suitability and willingness of the agents they nominate.

Special Register Information Service

A great part of the Branch's work consists in passing on information received from overseas to people who can make the best use of it here. This is done mostly through the Special Register Information Service, to which about 5,000 firms and trade associations subscribe. Some 10,000 calls for tender from overseas are advertised in this Service each year, and economic reports from overseas countries, and short market surveys for particular commodities in a large number of countries, are prepared and circulated from time to time.

We have recently started a special series in this register on the organisation of atomic work and openings for atomic nuclear plant and equipment in different countries. This has led to a good deal of interest on the part of firms in that field.

There are other ways in which the Branch can help. It can advise business visitors who are going to territories with which they are not familiar and can put them in touch with the commercial officers stationed there, who can often enable them to make useful business contacts. They can provide commercial status information about overseas firms and obtain samples of overseas goods for the use of British manufacturers.

In addition to the staff of the E.S.B. stationed in London, we have officers concerned with exports in each of our regional offices. They are always willing to call on firms and can often provide the same sort of information as can be obtained from headquarters, or can get it if they cannot give it themselves.

These, very briefly, are some of the services the Government can offer to the exporter who is out to sell in overseas markets. We are anxious that they should be more widely known and more fully used. I have already mentioned the great increase in the business of E.C.G.D., and the number of enquiries reaching the E.S.B. has increased substantially in the past three or four years. But we are continually coming across evidence that exporters and potential exporters do not know of the help that is there for the asking.

hard selling ahead

It must be clear to everyone that selling is going to be harder next year than it has been for a long time; indeed, I would say than it has been since before the War. Perhaps we have cried " Wolf ! " about this too often, but an ominous feature of the present situation is that for the first time since 1953 world trade has stopped expanding. Not only has the rapid expansion of recent years suddenly died away. There are some signs that the volume of international trade has begun to fall. The implications of this for our export trade could be serious. The recession in the United States and the present pause in the expansion in Western Europe, by restricting the domestic outlet for each country's production, will make the struggle for trade in other countries fiercer than ever.

Even when world trade was expanding rapidly our own exports were not expanding so fast. Now it will be vital for us to see that if world trade for the time being tends to contract, our share of it contracts less than the whole. We in the Government services are ready to do all we can to help and to examine quickly and sympathetically any constructive suggestions for improving the services that we offer.

DISCUSSION

THE **Chairman** said he was delighted at the information given by Mr. Hughes. He had always been under the impression that people did not make sufficient use of the Government services available to exporters, both in this country and more particularly overseas. Many people had told him they would not dream of going to the Embassy in the country they were visiting. It was his own experience that these services were given freely and in the most friendly way and were admirable. When he went abroad, he always called on the Ambassador and the commercial people, giving them notice in advance and telling them the kind of people he would like to meet. Almost always these people made themselves available, frequently over a pleasant luncheon, but always in circumstances such that one could get down to business with them, knowing they were the right people.

He asked whether Sir John Taylor could confirm that people travelling abroad did not make sufficient use of the services available to them.

Sir John Taylor said that this was quite true, although many more people were now making use of them. It was as well to write in advance giving some idea of the people it was desired to meet. These services could be particularly valuable to anyone seeking to enter a market for the first time.

Mr. Hughes said that new exporters who did not know the country they wished to export to should get in touch with the Regional Export Officer or with the Export Services Branch at Lacon House. A message would then be passed on to the commercial staff in the capital of the country concerned.

This was not a burden: it was something they wanted to encourage to help business people to export to other countries.

The **Chairman** said that one had no impression at all that one was involved with a Government Department. He thought any objection was psychological more than anything else.

He would like to ask a question about consumer goods or engineering goods that were normally bought by individuals or small producers like farmers. In many countries where there was a large native population with a fair amount of money, it was no good advertising in the press because people could not always read very well. They had to be shown the goods concerned. This might involve sending goods to an agent on consignment so that they could appear in the shops or warehouses where people coming to town from the country could see them, touch them and ask questions about how they worked.

Would any member of the Forum care to confirm that line of reasoning or otherwise ?

Sir John Taylor said he was in entire agreement and as an extension, a travelling caravan might go out to different districts showing what was for sale.

Mr. Whittaker said one would like to go personally to every consumer, demonstrate the article and show exactly what it would do, but the distances were too great.

With many consumer goods it was not much good putting things in the shops or even running exhibitions. One had to get people to come to see them, and this was exactly what advertising did. Advertising was necessary in many cases in order to persuade the potential customer that he wanted the goods. Unless he wanted them he would not be strongly tempted to go to see them, and there would be no opportunity of demonstrating them and convincing him of their usefulness.

In reply to the Chairman, who asked his opinion on elaborate packaging, Mr. Whittaker said that this was important. There were cases where the design of the packaging had made all the difference to successful big business. There was, however, a big problem here, because the sort of package design that appealed to the British might not appeal to the Fijian or the Nigerian, whose ideas of colour and form were entirely different. In many cases, both the package and the article were extremely important.

Dr. Hague said he agreed with the idea of going round and showing what one had. As an alternative, in the United States and Canada — in remote areas — a good deal of use was made of the Sears Roebuck type of operation for the small purchaser. As far as he was aware, not enough was done in the U.K. on similar lines. If equipment and materials were well illustrated in catalogues circulated, people were inclined to use the mail order procedure extensively.

The **Chairman** said he was interested in the suggestion that there was a tendency to design articles for too long a life. It sometimes worked the other way. He remembered being told by a former President of Nicaragua that a new turbine from England was to be put in during the following week. He had had equipment from England which had worked without trouble for 25 years and he said he could not buy a piece of equipment like that from any other country in the world. He had placed an order that very morning for 14 Land Rovers.

Dr. Hague agreed that in many instances design for a long life was desirable, but on occasion this was not necessarily so. In some instances, business was being lost to Continental suppliers because standards here were such that this country could not compete on a price basis.

A member of the audience said he had recently returned from America, Canada and other countries and he had had wonderful co-operation from the Department of the Board of Trade concerned. He had been able to obtain some very good contracts. Only that morning he had come back from Holland and the information given to the meeting would be very useful. What he was really interested in was the export to Russia of piano actions.

Mr. Hughes said he would be surprised if there were any obstacle on this side to selling piano actions to Russia, but he could well believe that the Russians were not very keen to buy them. It seemed to be a job of salesmanship in this case.

Dr. Hague said it was his experience that the Russians were very astute bargainers. However, once they finalised a contract they kept to it and they expected the other side also to keep to it very strictly.

The **Chairman** said he could confirm that the letter of the agreement mattered more to them than the spirit. Once it was signed, one was expected to deliver precisely as one had agreed and one was paid on the nail. There were no difficulties at all. If the speaker was concerned to know the general situation *vis-a-vis* this country and Russia, the Chairman thought the normal approach was to the Commercial Department of the Russian Embassy. Some people had sent their catalogues, descriptions and so forth, in English naturally, to the Soviet Embassy and heard nothing more. Others had had communications and ultimately enquiries, and in some cases orders.

In general, he thought there was a tendency for the Russians to buy a little more from the U.K., and there was, of course, a general tendency in Russia to increase the

supply of consumer goods. There was some evidence that they were purchasing more consumer goods abroad. This tendency might or might not grow. It depended entirely, he thought, upon the general political difficulties in Russia.

In reply to a further question as to whether help could be sought from the Department of the Board of Trade, in the same way as with other countries, **Mr. Hughes** said that it certainly could.

In reply to an enquiry as to whether the embargo on the export of highly technical equipment was not encouraging the Russians to proceed on their own lines rather faster than they would otherwise have done, **Mr. Hughes** said that this question was being examined in Paris at the moment, by the body on which we discussed with other Western countries what the embargo list was to be. One could only await the outcome of the talks.

Another member of the audience said he would like to take Mr. Hughes up on the assistance given by the E.C.G.D., particularly on deferred credit terms. His company made capital goods, and they had been offered a number of contracts abroad; but they could not accept them because they were unable to get cover from the E.C.G.D.

To give an example, the Indian Government required that payment for capital goods should be spread over five to seven years. The E.C.G.D. did not seem to be interested in anything less than half a million pounds, whereas his company were interested in £20,000 to £200,000, and they would not grant cover for anything like five years.

The same thing applied to Brazil.

The E.C.G.D. said "Sorry, the longest we can give is two years", and this was not very helpful. He wondered whether there was any chance of their attitude changing. He was under the impression that they only wanted to cover risks that were not very great and in several cases where there was an element of risk they were not very keen to help.

He believed that India would pull through and it was very unfortunate to have to turn down what must be quite a number of applications for capital goods because of the attitude of the E.C.G.D.

The **Chairman** said he was afraid Brazil was one of the E.C.G.D.'s bad bets. They really got it in the neck in Brazil and he recollected that at one time Brazil was barred because she was so much in debt to the U.K.

The question was one which he could not answer, and he doubted whether Mr. Hughes could answer it either.

Mr. Hughes said it must be remember first of all that E.C.G.D. was not subsidised. It did not make a profit, but it must not make a loss. It had to take a commercial view: whether a particular transaction was a good risk, and on what terms was something the man running the show must judge. Advice was given by an Advisory Council composed of very experienced people in the City.

Secondly, and this probably applied to the question about India, it was the general understanding among export credit institutions that they should not give a guarantee for longer than five years. It would not be in the interest of this country or other countries for credit to get longer and longer. If that happened, those with the longest credit resources would win in the end, and he rather doubted whether this country would be among them.

The **Chairman** asked whether one of the troubles was not that the Export-Import Bank gave five years?

Mr. Hughes said he believed it did two types of business — real long-term credit running up to 20 years, and something comparable with the E.C.G.D. period. He understood they did not usually go beyond five years except in a few special cases, such as the very big jet aircraft.

Mr. Whittaker said his company was not in capital goods and they did not have to finance 200 or a million pounds for five to seven years. But they had very comfortably for a number of years carried their own risk.

Mr. W. F. S. Woodford (*Secretary of the Institution*) said he thought more attention should be devoted to embargoes on so-called strategic materials. With a number of production engineers he had just visited Poland and they had seen in Polish factories German machines which were known to be on the embargo list. The comment had been made: "The trouble with you British is you're far too honest".

Another speaker said the same thing happened in France, where there were certain instruments that were not allowed to be exported from this country. Something must be done about this and the Government Department concerned was notified of such cases, but it was as well to mention them at the present Conference so that people knew what was happening. Frankly, he thought the biggest reason why this country was in its present trading position was the political risk. There were far too many politicians at the moment and not enough statesmen.

Mr. Hughes said statements of this kind had been made on a number of occasions and although he was not directly concerned with the embargo list, he understood that they had not been substantiated. Obviously, the Eastern bloc countries would have a motive for spreading stories about German machine tools. If there were first-hand facts his Department would be very interested to have them.

A comment was made that in his interesting talk Mr. Whittaker had not stressed the great need for the salesman to know all sides of the problem. He must not only have the team spirit; he must have a wide knowledge of the articles he was going to sell so as to be able to discuss them with the customer. He must also know a great deal about the state of world markets and requirements.

There was another point. Surely engineers and people with experience did not just give the customer what he asked for. They had something to offer to the world, and people going abroad had an opportunity to educate the customer to want something better. It would pay him in the long run to have a better article and this country was noted for the high quality of its products.

The **Chairman** said there was a difference between consumer goods and heavier goods. In consumer markets the consumer wanted what he or she wanted, and that was what he had to be given. In engineering, on the other hand, there might be advanced products he knew nothing about.

Mr. Whittaker said it was, of course, axiomatic that one tried to sell what one wanted the consumer to have, but one had sometimes to make a choice between having a factory working on goods that the consumer would buy, as compared with having a factory doing nothing while one tried to persuade the customer he ought to have what one could make. It was a question of adjustment and doing the commonsense thing at the right time, using persuasion whether for consumer or other goods at some point if one felt an article was an improvement on what the customer had hitherto known and used or was accustomed to. But there came a time sometimes when with specialised goods one had to bow to the customer.

It was axiomatic again that the salesman should have full information. Anybody who tried to sell anything without knowing practically all there was to know about it was wasting his time. He would never do any good.

Dr. Hague said it must be remembered that in Latin-American countries — whether one liked it or not — British goods would have to stand comparison with American products. The packaging, presentation and after-sales service given by the American companies to the oil industry, for example, Venezuela, Colombia, Brazil, Argentina, was good. There must be developments, but the basic problem in his own industry, the oil industry, was cost. Bearing this in mind, it was important that new products and developments should be tried out and "snags" corrected before they were offered for service in South American countries. He realised that there was a vicious circle element about this, but sound commonsense supported this concept.

It was agreed, by the original speaker, that this was a very important point. The salesman should know his product thoroughly and many firms insisted on this though others did not. Spares should be available. Deliveries should be prompt. Representatives going abroad should be practical people as well as business people. They should get on the floor of the shop before going abroad to make sure that they knew all there was to be known about the product. This was what he called co-ordination of production with sales.

Dr. Hague said there were two comments he might make. On one occasion there was an engine on which they wanted to standardise, but eventually it had to be ruled out because the manufacturer could not offer a reasonable spare parts service, and quoted two years for orders for spares. Manufacturers should bear in mind that the only way to ensure continuous operation of such equipment was for the customer to hold large and uneconomic stocks of spares.

A point that was sometimes overlooked by British suppliers was that something that worked well in a temperate climate did not work at all well in the tropics. This constituted quite a problem with many pieces of equipment.

Another member of the audience said he had been told that the Canadians were encouraging an increase in exports from this country, but one serious difficulty that was putting off a lot of small manufacturers of electrical equipment was Canadian standards. Not only was it a lengthy business but one was expected, as it were, to sign a blank cheque for a completely unknown amount to get one's material approved. Many small firms really could not undertake the risk.

He would like to emphasise this, because his own company had a very heavy bill, before they built up a market for a new model, that they had to meet on the nail.

There was also a very urgent need to speed up the B.S.I. handling committee over here. The B.S.I. were very understaffed and it was difficult to get anything done quickly.

The **Chairman** said that the question of Canadian standards and — indeed — electrical standards in America was always with them. There was nothing one could do about it except put up with it. Was speeding up necessary at the Canadian end or at this end ?

The speaker said he thought it was necessary at the Canadian end in the laboratories in Toronto, but there was a need for bigger capacity for handling in the first place at this end. He would like it put forward as an urgent matter. Many electrical firms would like pressure brought to bear.

The **Chairman** said he was in a position to bring a lot of pressure to bear in anything of that nature that affected British trade.

An attempt might at least be made to speed up the process. He thought something could be done to iron out the difficulties and the snags. There was a new spirit abroad both in the High Commissioner's office in London and in Ottawa to try to get things done, and he happened to have his finger right in the middle of it.

The **President of the Institution** (*Lord Halsbury*) said he would like to hear the views of the panel on a question touched upon by Dr. Hague.

Britain was exporting in competition with other countries. If a British exporter could not break into a new market without first studying that market as recommended by Sir John Taylor, nor could his opposite number in Germany who wanted to do the same.

If he had to provide certain spare parts for his sales service and maintenance, as recommended by Dr. Hague, so must his Japanese competitor provide them.

If some of the difficulties referred to by Mr. Whittaker were experienced, it must be because the salesman and the production engineer were pulling in opposite directions. The salesman was trying to diversify the product as much as possible, because it was then easier to sell. The production engineer was trying to standardise as much as possible, because it was then easier to make. They could not both have their way. They must fix on some optimum compromise. The nature of that compromise would not be different because their mother tongue happened to be French or Italian rather than English.

Mr. Hughes had referred to the commercial policy of the E.C.G.D. Whatever public body supported the German or Japanese exporter with credits, if the E.C.G.D. did not think a particular customer was a good bet for six years' credit neither would the body on the other side of the sea, wherever it might be. These considerations were of universal application.

If there were difficulties for this country, there were difficulties for everyone else. The other chap had his difficulties too. Why were ours supposed to be different ?

To some extent, the very fact of holding a Forum such as this implied some dissatisfaction with the way exporters were doing their job. They were obviously not doing it very badly because this country was the world's largest exporter, as it had always been. It seemed strange for a country that had been the world's largest exporter for so long that these matters were not to some extent intuitively obvious. Was the panel satisfied that the average exporter was maintaining as high a standard of skill and technique in export as he ought to be, in comparison with his competitors ?

Dr. Hague said that, looking back over the post-War years, his own basic reaction was that an easy home market in the U.K. had enabled suppliers to fill their order books with comparative ease. Why, therefore, should British suppliers make special efforts to sell overseas ? There was, in fact, in many cases no great inducement to cultivate export markets unless and until order books could no longer be filled. This, he admitted, was an over-simplification of the problem.

Mr. Whittaker said that while the U.K. had for long been the greatest exporter nation, other people had gone a long way towards catching up. The comparison should, he thought, be made not between the largest organisations, but between the medium and smaller organisations. It was his own feeling that competing countries had improved their standards of production and selling and technique generally, whereas this country had not improved to the same degree. Therefore, the gap between them had narrowed.

The **Chairman** said the question was whether exporters were doing as well as they could.

Sir John Taylor said the spirit of enterprise was still with this country. Who would have thought it possible to sell half-a-million oil stoves to the Persian Gulf ? This was what an enterprising salesman had done last year. It was very cold after sundown for three months of the year and he would not be at all surprised if some enterprising woollen merchant found a market there for woollens.

The **Chairman** commented that by and large, looking at industry as a whole, this country was putting forward the best effort that was possible. The members of the Forum agreed.

The **President** (*Lord Halsbury*) said he quite appreciated that people with a steady home market might not wish to expand into the export market. But there was surely a difference between a positive wish not to export to a particular market and exporting to it in a slapdash way in the opposite case. If one entered a market to sell something, one would have to give the best possible type of sales service. It was quite another matter if for policy reasons one decided not to go into that market.

(*continued on page* 643)

The Design of Automatic Machine Tools for Electronic Control

by F. Koenigsberger, D.Sc., M.I.Mech.E., M.I.Prod.E.

A Paper presented at the Production Conference, Olympia, on 16th May, 1958.

I. Introduction

AUTOMATIC control and operation of metal cutting machine tools is not new and was in use long before the term "automation" had been created. When the power drive was introduced for rotating the work spindles of lathes, drilling and milling machines, when mechanically-driven feed movements replaced hand operation, in other words, as soon as the power requirements and the operational steadiness and consistency of cutting and feed motions were not left to the manual control of the operator, these "mechanisations" represented the first steps of "automation" in the field of machine tools.

This did not mean, however, that the services of an operator were no longer required during the actual working of the machine. As the brain which had to control the available power the operator still had to set, start and stop the various mechanisms which carried out the required operations.

Complete automation, i.e. elimination of the need for the presence of an operator, once the machine had been started, was achieved by the introduction of cams and trip dogs in automatic lathes. These produce batches of complete work-pieces in a predetermined sequence of different operations with a variety of cutting tools until the material supply is exhausted. The cams or trip dogs operate the feeding and clamping of the work-piece material, the starting, stopping and reversing of the main spindle (at different speeds, if necessary) the moving into position of the tools required for each operation and the appropriate slow or fast feed movements of the tool slides.

For each operational step of these machines a specific tool (or set of tools) appropriately set for the required depth of cut, has to be brought into its working position, and by means of a corresponding cam the length and the rate of traverse are determined.

Apart from the power of the spindle drive, the cutting capacity depends upon the strength of the cams and the lever gears transmitting the feed drive to the tool slides, and these same feed actuating mechanisms may also have to determine the dimensional accuracy with which each operation can be carried out.

The principle, in which driving power and dimensional determination of working strokes are assigned to the same machine elements, has been abandoned in many high precision machine tools such as jig borers. It is also avoided in machines in which trip dogs directly attached to moving tables or slides actuate clutches, thus controlling the movements in accordance with the required position of the driven and not the driving parts. For example, in milling machines a degree of automation is obtained through cams or trip dogs controlling a sequence of feeding, quick traversing, reversing and stopping, once the operator has started the machine. The design of template controlled following devices may be considered a development of the trip dog idea, with a single purpose trip dog of infinitely variable profile.

The outstanding feature of the automatic machines previously mentioned is the fact that, once set up, they can carry out singly or repeat over and over again the same sequence of operational movements. They are, in fact, universal machines which, through the

provision and setting of stops, tools, fixtures and specially designed cams become single purpose machine tools. Like such machines they are, for economy if for no other reasons, suitable mainly for the production of large quantities of identical work-pieces, the quality of which depends on:

1. the accuracy to which the machine has been manufactured;
2. the degree and consistency of the working accuracy of the machine, i.e. the strength, rigidity and resistance to mechanical wear of the operating mechanisms and tools;
3. the standard of care and precision applied by the operator when setting up the machine.

The rate of output of these machines depends on:

1. the operational forces which can be handled by the various elements without excessive deformation and wear;
2. the working speeds and power capacity;
3. the time required to control the different operations.

Recent developments have produced hydraulic, pneumatic, and electrical devices capable of controlling machining operations by translating instructions and results of independent measuring operations into control impulses for adjusting and driving mechanisms. The application of such devices permits the production of complex shapes and profiles which were previously obtainable only by means of hand-made templates or cams. As the expression and transmission of instructions can be achieved by electronic means with greater accuracy, speed and economy than is possible mechanically or manually and in machine tools of orthodox design, a completely fresh approach to the principles of machine tool design is necessary. In order to appreciate the problems involved, it may be pertinent at this juncture to review the general requirements for the design of machine tools both for manual and automatic operations.

II. Design Requirements for Machine Tools

Metal cutting machine tools have to produce, by chip removal, work-pieces of specified shapes and sizes. In order to carry out this work economically, competitively and within prescribed limits of dimensional accuracy and surface quality, they must satisfy the following requirements:-

(a) performance

1. *Quantitative*: The volume of metal removed per unit time must be large. This aspect of productivity of a machine tool must be judged, of course, with discretion. Over 30 years ago, Schlesinger drew attention to the fact that "the weight of chips is less important than the number of work-pieces produced by a machine tool in a given time. Machine tools are usually not designed and built for use in chip factories, but for use in engineering workshops".

Frequently, however, the volume of metal removed per unit time greatly influences the possible output of work-pieces, especially in the case of roughing operations. A machine tool must be designed, therefore, to make full use of the tools and tool materials available for high speed cutting conditions. This implies that suitable speeds and feeds are provided, that the machine structure and the devices for locating and clamping tools and workpieces have the stiffness and rigidity necessary to cope with the large operational forces and the conditions of their

Dr. Koenigsberger joined the Manchester College of Technology (now The Manchester College of Science and Technology) in 1947, and is now Reader in Machine Tools and Production Processes. He received his technical education at the Technical University, Berlin-Charlottenburg, where he graduated in 1931. After a period as Assistant to the late Dr. George Schlesinger, he worked as a senior draughtsman and designer in several machine tool firms on the Continent, his last job being that of chief engineer and chief designer of the Machine Tool Department of Ansaldo in Genoa, Italy. He came to the United Kingdom in 1938, and joined Cooke and Ferguson Ltd., of Manchester, subsequently becoming Chief Mechanical Engineer and Designer, mainly in connection with welded machinery structures.

Dr. Koenigsberger has served on Committees of the British Welding Research Association, the Institute of Welding, the Institution of Mechanical Engineers, and the British Standards Institution. He is a British delegate to the International Institute of Welding, and to the International Standards Organisation, and was a member of the British delegation at the Conference of Production Engineering Professors, organised in Delft by The Institution of Production Engineers in 1956.

application, and that the elements of drives, gears, bearings, etc. are designed for the transmission of the power required. In addition, the provision of auxiliary devices for cooling and swarf removal is important.

2. *Qualitative*: The specified accuracy of shape and dimensions of the workpiece as well as the required quality of surface finish must be obtained consistently.

The quality of machining may be influenced by factors other than the machine tool itself. Examples are the cutting tools (type and material, rake angles, roughness of the cutting faces), the rigidity and strength of tool holders (boring bar, milling arbor), the machinability and rigidity of the work-piece itself, the strength and stiffness of clamping devices, the selected settings (cutting speed, depth of cut, and feed rate) and any changes in the operational conditions which may occur during the progress of the work (wear and crater formation at the cutting edge, temperature changes in the cutting zone, etc.). Here again provision for obtaining optimum conditions must be made in the design of the machine.

The shape and size of the finished workpiece depends only on its track in relation to the cutting edge, and this is determined primarily by the instantaneous positions of the parts which carry the workpiece and the cutting tool. As long as the machine is not actually working, errors in these positions depend on fits and alignments, i.e. on the quality to which the machine tool has been manufactured. As soon as the machine begins to work, however, functional errors in the control devices as well as deformations and displacements under the cutting and driving forces make the influence of the design, strength, stiffness and freedom from vibration of the operative parts, a decisive factor.

(b) operation

1. *Preparation of the machine for each particular job (setting-up)*: Ease in the correct and fool-proof adjustment of the machine settings, and rapidity in the setting-up of fixtures and in the setting and replacement of cutting tools reduce the times during which the machine is not actually in production.

2. *Manual control of the machine*: The better the reach and accessibility of control devices and the easier and lighter the efforts required for carrying out control operations the shorter will be the auxiliary (non-productive) times prior to, between and after cutting operations. These non-productive operations preceding or following each cut and — on machines with manual control — carried out by the operator are:

1. setting, clamping, unclamping and removing the workpiece;
2. bringing the tool in position for each cut;
3. selection of correct speed and feed;
4. approach of tool into cutting position;
5. engagement of mechanical movements;
6. stopping of mechanical movements;
7. measuring and — if necessary — repeating operation until the correct dimensions of the workpiece are obtained.

3. *Automatic control of the machine*: The cutting speed and power of each operation need not necessarily differ in the case of manually and automatically controlled machines. In an automatic machine it is possible, however, to control several operations simultaneously, and the total power requirements may, therefore, be higher. Moreover, the output of automatic machines is greatly increased by the reduction of the before-mentioned non-productive times between actual cutting operations.

(c) maintenance

Loss of productive capacity may occur through need for repair or general maintenance. The provision of easy adjustments and replacements and, last but not least, the prevention of wear or damage will enable maintenance to be planned instead of repairs by default becoming necessary.

The greater the productive capacity of the machine the more important becomes the question of maintenance.

III. Application of Electronics

In the cam-operated automatic machine, the purely manual actions of the operator are taken over by mechanical devices in a predetermined sequence and irrespective of their actual effect on the operation in question. If, for example, due to some mechanical mishap a clutch operating lever failed to engage the drive for a mechanical movement, the cam actuating the following operation might still carry out its job irrespective of the fact that the previous operation had not taken place. In other words, the supervision and checking, i.e. the brain work, if and when required, would still have to be carried out by the operator.

Much has been talked about so-called "electronic brains", but these machines can do their work only after all the necessary information has been supplied to them in the correct form, whilst of course, the human brain is able to collect this information and to convert it, if necessary, prior to commencing its work.

The information necessary for a machining operation is usually supplied by means of a drawing or a planning card, and, once this is available and translated into suitable form, electronic devices can be used to initiate or duplicate practically all the work otherwise done by a manual operator. This includes the checking and measuring of movements and the correction, before proceeding to the following operation, of errors which may have occurred. The exception would be unforeseeable complete breakdown; in this case, however, the machine could still be switched off automatically.

Moreover, electronic devices can employ the equivalent of more than two eyes, two hands and one brain, and their working speed is not limited by the inertia of moving masses encountered in cam operation. They can work faster, therefore, and carry out more operations simultaneously than can be achieved by a human operator or by cam control. In addition, high precision measuring devices, optical, pneumatic or electronic, can be coupled to electronic equipment. The accuracy of measuring and control goes, therefore, well beyond that hitherto commercially obtainable in automatic machine tools and thus opens the way to manufacture for truly non-selective assembly.

The simultaneous execution of several operations producing a higher total of cutting forces in action at any time and the greater operational speeds result in a higher rate of metal removal and in increased productivity.

From the foregoing remarks it will be appreciated that the following points need special consideration :-

1. Operational forces and speeds determine the power requirements of the machine. The higher these power values, the more important become the problems of providing the necessary power and at the same time preventing power wastage which may be caused either by the provision of unnecessarily large power units or by excessive power losses in the machine. Power losses must, therefore, be reduced and power requirements more accurately determined than has been the case in orthodox design practice.

2. Measuring and positioning devices should preferably refer to the cutting edge and the workpiece and not to the tool slide and the work table. Otherwise inaccuracies of slide-ways, spindles, etc. will escape detection and jeopardise the quality of the workpiece.

   However, it may often be found impracticable if not impossible, to measure directly on the tool or workpiece. In such cases, special precautions must be taken for producing the machine to an accuracy equal or superior to that of the measuring devices or, alternatively, to correct to within the required limits the results of unavoidable machine inaccuracies if and when they arise. Tool wear can be measured or the tool can be reground to a specified size at regular intervals. At the same time the machine settings and controls must be, of course, suitably adjusted.

3. The automatic control of the machine tool involves not only the mere transmission of the necessary operating instructions but also a continued comparison with the results obtained. The need for continuously applying corrective action necessitates the use of feed back control devices, i.e. servo-mechanisms. The purpose of such servo-mechanisms, which control the various operations, drives and movements, is, therefore, to position the various parts in such a manner as to keep the differences between the input information (theoretically required position) and the output of the measuring devices (actual position) within prescribed limits. In the case of pure positioning operations, as found, for instance, in jig boring machines, the time at which table and saddle reach their required positions is not critical, as long as each part is in position and clamped before the tool starts cutting.

In profiling and similar machines the instantaneous relative positions of the parts, which move while cutting is in progress, must continuously remain correct. This is not a question of just controlling the velocities of the various moving parts; in fact, errors in velocity or acceleration as such are only important as far as they affect the relative positions of the moving parts which have to be within the permissible limits at any moment of the operation. The closing of the loop between position measurement and control input must be such, therefore, as to provide rapid action on the part of the control devices, and it may be necessary to establish limits for the demanded accelerations.

If all conditions during machining operations, such as the inaccuracy of the machine, the time lag of the drive mechanism, the cutting resistances at any moment, etc., were predictable, accuracy of the final product could still be obtained by proper calibration and corresponding adjustments of the input data to correct the errors. Some of these calibrations would have to be repeated, however, for each particular job, and, moreover, practical conditions are likely to change, thus altering the parameters of the calibration.

No relaxation of the stringent conditions in design and manufacture is, therefore, possible, and the nature, order, stiffness, frequency response and stability margin of the servo-mechanism must be such as to produce high speed, high precision machining operations.

These problems are, in matter as well as in degree, so different from those hitherto encountered and solved often purely empirically by machine tool designers, that a more fundamental approach is essential, which tackles the job almost from first principles. This applies to methods, layouts, shapes, sizes and proportions. Calculations rather than estimates are often necessary, and in order to start such calculations a considerable amount of new information must be made available.

This means a combined operation between scientist and designer and the use of methods which would have appeared out of place in an industrial workshop not many years ago. This co-operation represents more than just applied research. It is research into design problems, the results of which are immediately tried out on design development, thus closing, as it were, the loop of the exercise. Work thus undertaken may well be frowned upon at first by both practical designers and academic research workers, the former claiming that their sound

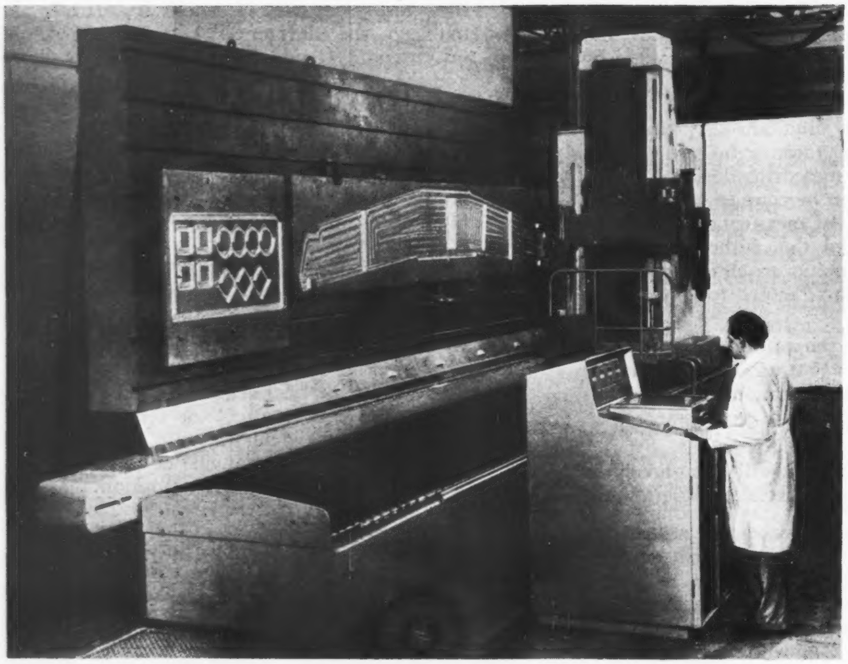

Fig. 1.
Three-dimensional high speed contour milling machine.
(The Fairey Aviation Co. Ltd., Stockport.)

Machine Weight	50 tons (total)
Table Weight	26 tons
Column Weight	$8\frac{1}{2}$ tons (on X Slide)
Vertical Saddle Weight	1 ton (on Y Slide)
Head Slide Weight	$\frac{1}{2}$ ton (on Z Slide)
Table Size	28 ft. × 8 ft.

	Traverse	*Speed (cutting)*	*Fast traverse*
X ...	25 ft.	0 - 120 in./min.	150 in./min.
Y ...	7 ft.	0 - 120 in./min.	150 in./min.
Z ...	12 in.	0 - 60 in./min.	75 in./min.

Drive Thrust on X = 8,600 lb.
Drive Thrust on Y = 4,000 lb.
Drive Thrust on Z = 1,000 lb.

Cutting Head on Machine:

Speed — 6,000 r.p.m. from 100 cycles/secs. supply. D.C. injection braking stops in a few seconds.

Slideways:

Slide friction with test load of 9 tons. No static friction. Friction is purely viscous and varies with speed.

Diffraction Grating Equipment:

Gratings on all axes are 500 lines per in., which, with 2 pulses per line, gives 1 pulse = .001 in.

Z gratings are in one piece.

X and Y gratings are in 10 in. lengths, held at one point in centre of length, so that with temperature variations the glass moves with the casting. The small movement between adjoining gratings over this 10 in. length is too small to affect the signal. Gratings accuracy is ± .0005 in. per 10 in. — not accumulative.

Gear Boxes:

On X and Y are double trains with spur and helical gears with two rack pinions.

The anti-backlash preload system loads the two rack pinions against the rack in opposite directions.

Moving in one direction, one gear train and one rack pinion transmit the drive power, absorbing the preload, but always leaving a residual load on the other train which is actually backdriven by the rack. At maximum power input this residual load on the non-driving train is 10% of full input. With no input load, the preload is equally shared between the two trains.

The Z gearbox is a standard Ferranti double train box with a modified input to suit the hydraulic motor. The drive is to a $\frac{1}{2}$ in. pitch recirculating ball leadscrew with double nut preload to 1,200 lb.

Gearboxes have all been designed for low inertia and high stiffness.

Oil lubrication on X. Mist lubrication on Y and Z.

Hydraulic system pressure ...	2,000 p.s.i. approx.
Balance cylinder pressure ...	1,000 p.s.i.

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experience does not need academic assistance and the latter objecting to research which is not purely looking for absolute truth, but which judges its value from the point of view of its immediate applicability to the solutions of practical industrial problems. These opinions may, of course, be reversed if such work will provide the designer with material unobtainable from his experience and obtained by means of a sound scientific approach to and execution of the work in question.

In order to gain the full benefit from work of this kind it is essential to tackle it simultaneously from the mechanical and the electrical engineering angle. At present it is often found that a company of electronic engineers supplies standard equipment to be used in conjunction with more or less standard machine tools manufactured by another company. Combined simultaneous efforts of a team consisting of mechanical engineers experienced in machine tool development, and electrical engineers specialising in the development of electronic equipment, will result not only in each side appreciating and trying to satisfy the needs of the other side, but also in a cross-fertilisation of ideas which will be beneficial to everybody concerned.

In an industrial application such teamwork has produced the machine (Fig. 1) which incorporates the most advanced design principles and ideas in the field of electronically controlled machine tools. A research project dealing with the fundamental development of design elements for electronically controlled machine tools is at present in progress at The Manchester College of Science and Technology and is sponsored by the National Research Development Corporation.

IV. Machine tool design

(a) forces and power requirements

Numerous investigations and researches have been carried out to study the mechanism of metal cutting, and some information has been published concerning the recommended speeds and the resistances encountered in cutting various types of materials under

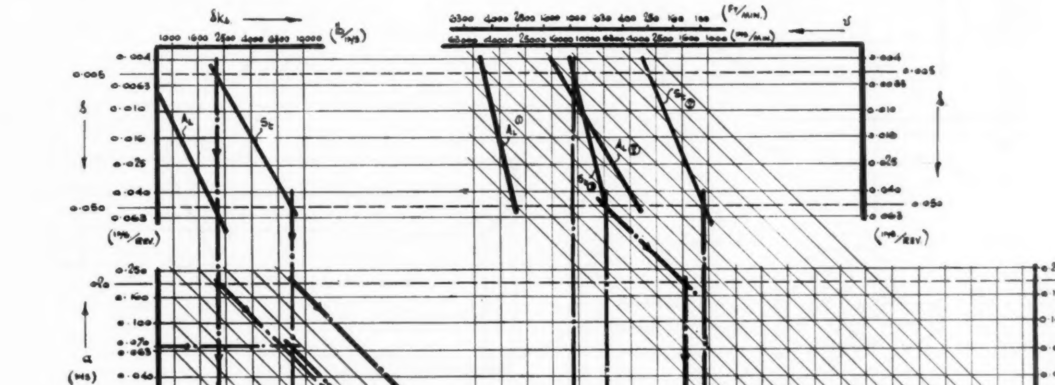


Fig. 2. Nomogram for the determination of working capacity and power requirements during turning operations.

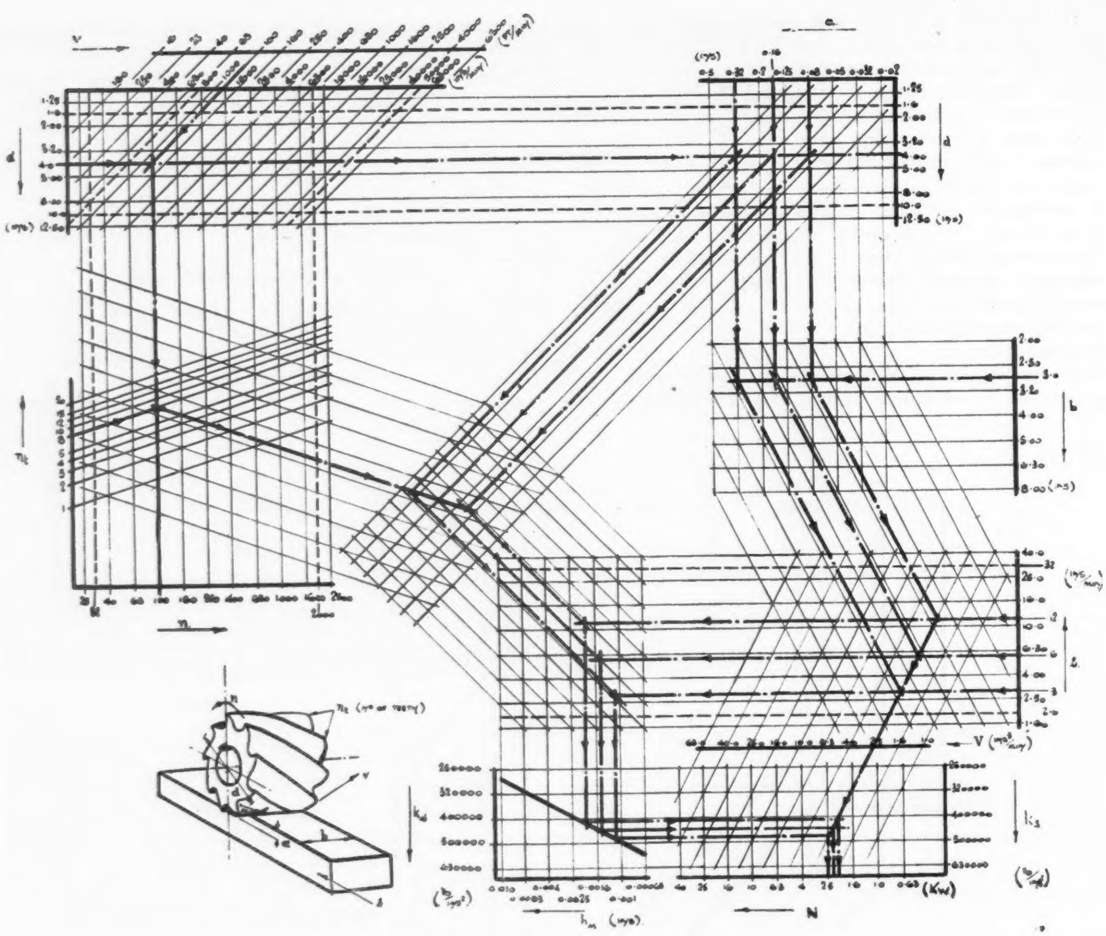


Fig. 3. Nomogram for the determination of working capacity and power requirements during slab milling operations with helical cutters.

different operational conditions. The variety of materials and operations which have to be dealt with by many machine tools often result in contradictory design requirements, so that in many cases compromise solutions have to be found. The necessary calculations, although not difficult, may become rather cumbersome, and graphical aids, e.g. nomograms, may help in speeding up the work.

Although nomograms are usually less accurate than exact calculations, they not only show the actual results of calculations concerning particular working conditions, but also give a clear picture of the trend of results obtainable by modifying some of these conditions.

Nomograms which can be used either for determining design data from working specifications or for judging the conditions under which a machine tool of a given design can be operated most efficiently, were developed by Hucks [1], Kienzle and Victor [2], Schlesinger [4], and others. Some of these are rather involved, and suggestions are therefore made for nomograms dealing with the lathe (Fig. 2) and the horizontal milling machine (Fig. 3), which may cover the subject sufficiently without being over-complicated.

The use of log-log systems results in the various relationships appearing as straight line functions, and the employment of preferred numbers (geometrical progression) for the parameters gives equal distances between the ordinate lines.

It is not proposed to dwell extensively on explanations for the use of the nomograms, as it is hoped that these will be self-explanatory; it will suffice to state the data and equations on which they are based.

For the case of the lathe (Fig. 2) the values for recommended cutting speeds (v) and specific cutting resistances (k_s) as functions of the feed (s) are taken from German recommendations (AWF158).

Spindle speed :

$$n = \frac{12v}{\pi d} \text{(n in r.p.m., v in ft./min., d in inches).}$$

Tangential cutting force component :

$$P_1 = a.s.k_s \text{ (}P_1\text{ in lb., a in inches, }k_s\text{ in lb./in.}^2\text{).}$$

Net cutting power :

$$N = \frac{P_1 \ v}{44200} \text{ (N in kW)}$$

Spindle torque :

$$T = \frac{P_1 d}{2} \text{ (T in lb. in.)}$$

Rate of metal removal :

$$V = 12 \text{ v.a.s. (V in in.}^3\text{/min.).}$$

The tangential cutting force component (P_{1w}) acting in the middle of the workpiece (length l) and causing a deflection (δ_1) is :

$$P_{1w} = 2.35 \ E\delta_1 \left(\frac{d}{l}\right)^3 d$$

For a steel workpiece (E = 30,000,000 lb./sq. in.), a minimum value of $\frac{d}{l} = \frac{1}{6}$ and a maximum permissible deflection δ_1 = 0.002 in. the force becomes :

$P_{1w} \simeq 650 \ d$

(entered as a chain-dotted line in the bottom right-hand corner of the nomogram).

For better understanding the following example has been drawn into the nomogram by means of dotted lines :-

Maximum diameter to be turned		8 in.
Minimum diameter to be turned		0.8 in.
Maximum spindle speed ...	...	5,000 r.p.m.
Minimum spindle speed ...	...	125 r.p.m.
Maximum feed rate ...	...	0.05 in./rev.
Minimum feed rate ...	...	0.005 in./rev.
Maximum depth of cut ...	...	0.20 in.
Minimum depth of cut ...	...	0.02 in.

For a simple example (chain-dotted lines) of machining mild steel with tungsten-carbide tools the recommended cutting speeds (St_1) require spindle speeds of about 250 r.p.m. to 4,500 r.p.m. for the specified diameter range. These spindle speeds are provided. For the case of machining mild steel with high speed steel tools (St_2) with a maximum feed rate the spindle speed range would only allow the permissible cutting speed to be obtained up to a workpiece diameter of 2.9 in. The largest cutting force would occur when machining the maximum depth of cut with the highest feed rate, when a force of 1,620 lb. would limit the minimum diameter which could be machined to 2.5 in. with a resulting spindle torque of 2,020 lb. in. and a net cutting power of about 20 kW. The rate of metal removal is in this case 60 in.³/min. The minimum diameter of 0.8 in. could only support a cutting force of about 500 lb. which at maximum feed rate would allow a depth of cut of 0.07 in. If the maximum depth of cut is used together with the minimum feed rate the net power requirement drops to about 10 kW.

For the case of the milling machine (Fig. 3).

Spindle speed :

$$n = \frac{12v}{\pi d} \text{ (n in r.p.m., v in ft. min., d in inches).}$$

Middle chip thickness * :

$$hm = \frac{s}{n.n_t} \sqrt{\frac{a}{d}}$$ (h_m in inches, s in in./min., n_t = number of teeth of the milling cutter, a in inches).

Specific cutting pressure :

k_s = f (h_m) (k_s in lb./in.² from experimental results).

Rate of metal removal :

$$V = a.b.s. \text{ (V in in.}^3\text{/min., b in inches).}$$

Mean net cutting power :

$$N = \frac{k_s abs}{530000} \text{ (N in kW)}$$

The following simple example is shown in the nomogram by means of dotted lines :

Maximum cutter diameter	...	10 in.
Minimum cutter diameter	...	1.6 in.
Maximum spindle speed ...	...	2,000 r.p.m.
Minimum spindle speed ...	...	32 r.p.m.
Maximum feed rate ...	...	32 in./min.
Minimum feed rate ...	...	2 in./min.

A cut 0.16 in. deep, 3 in. wide has to be taken in a mild steel workpiece with a cutter of 4 in. diameter, 8 teeth, at a cutting speed of 100 ft./min. At a feed rate of 6 in./min. the net power requirement for the cutter will be 2.2 kW.

The well-known fact that the power requirement is not proportional only to the rate of metal removal can be clearly seen from the following. If the same rate of metal removal (2.5 in.³) is to be obtained by doubling the depth of cut and halving the feed rate the power requirement increases to 2.5 kW, whilst it drops to 2.0 kW if the feed rate is doubled and the depth of cut is halved.

The values for recommended cutting speeds and feeds and for specific cutting pressures in the nomograms depend, of course, on materials, types, sizes and shapes of the tools employed, and investigations concerning these will, therefore, influence and should be carried out in parallel with the design and development of the machine tools themselves.

Figs. 4 and 5 show milling force dynamometers and Figs. 6 and 7 lathe dynamometers, used in the Royce Laboratory of The Manchester College of Science and Technology.

* See G. Schlesinger [5].

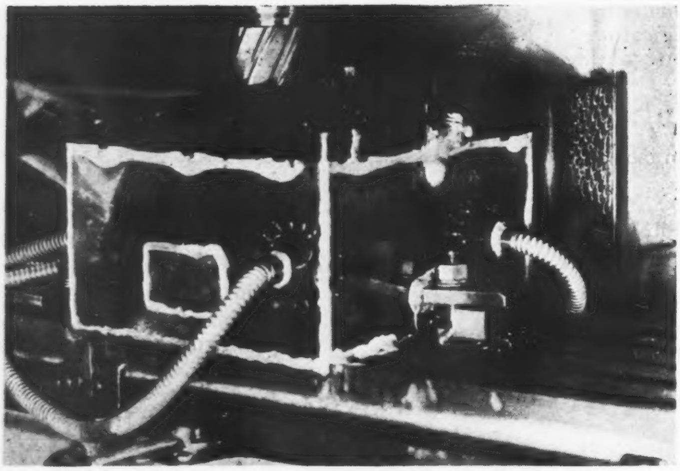


Fig. 4. Three-dimensional milling force dynamometer (electrical resistance strain gauge measurements).

(b) accuracy of alignments

The alignments of the various parts of the machine tool depend on :-

1. displacements under load;
2. the accuracy of manufacture;
3. wear of slideways, bearings, etc.

Displacements under load depend on the stiffness of the load carrying elements, structural parts, oil films, etc. Structures combining high stiffness with low weight are advantageous, particularly from the point of view of vibrational rigidity, and the light weight welded steel construction method, already successfully introduced in many fields of engineering* should prove its value in the design of machine tools which have to work at high operational speeds. One of the outstanding features of this method is the possibility of distributing the material most favourably in structural elements and sections, making full use of the material properties, a feature which cannot always be achieved in cast structures.

Fig. 8 compares strength and stiffness in bending (suffix b), and torsion (suffix t) for four typical sections having equal cross-sectional areas (i.e. weights per unit length) and equal depths (d). The sections are :-

1. the simple rectangular section;
2. the H-section;
3. the tubular section;
4. the rectangular closed box section.

It will be seen that within the practical range of width/depth ratio (k), the closed box section is the most favourable, its slight inferiority to the tubular section in torsion being more than compensated for by its qualities in bending. It can be proved * that as the depth (d) of a closed box section increases, for specified values of stiffness in bending and/or stiffness in torsion, the cross-sectional area and with it the weight of material in the beam decreases in pro-

* See F. Koenigsberger [3].

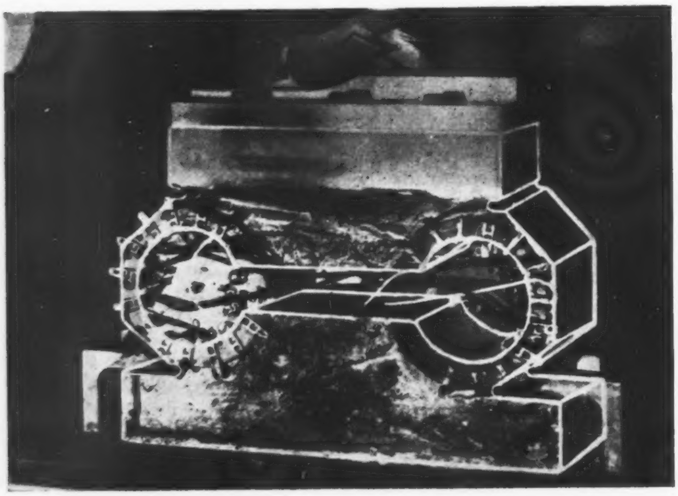


Fig. 5. Two-dimensional milling force dynamometer (electrical resistance strain gauge measurements).

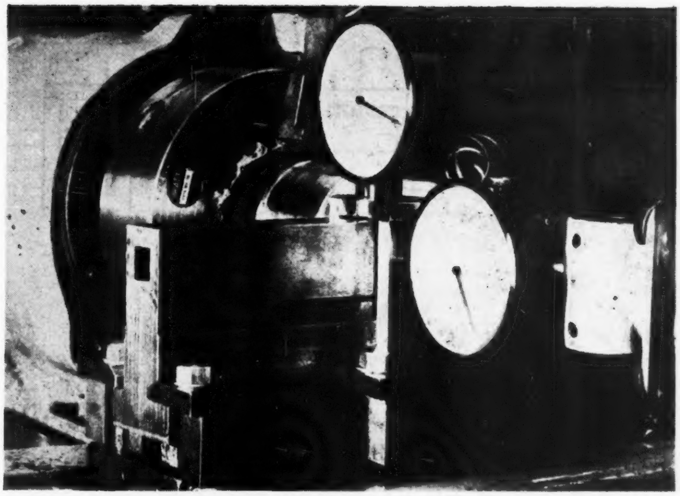


Fig. 6. Two-dimensional lathe dynamometer with dial gauge indicators (developed by Dr. W. B. Heginbotham, The Manchester College of Science and Technology).

portion to d^2. Structures of specified strength and stiffness conditions and of very low weight can thus be obtained by using box sections of large overall dimensions with very thin walls.

Against the favourable properties of thin-walled large box sections, however, a limitation of their loading capacity arises from the danger of warping and buckling of the thin walls under the shearing stresses. As the buckling load decreases with the square of the width of the wall and increases with the cube of the wall thickness, the danger of walls buckling is greatest in sections of large overall size and small wall thickness. Furthermore, the lower the stiffness against buckling, the greater is the danger of resonance vibrations in the panels forming the walls of a box section.

The requirements of strength, stiffness and vibrational rigidity of the sheet panels are therefore directly opposed to those which concern the box section as a whole. In the "shell" type construction the thin walls of the panels are therefore individually stiffened either by webs or by suitable bends or corrugations in the sheet metal. In the "cellular construction" method, used in the "Diskus" grinding machine structures (Fig. 9), the box sections are sub-divided into small cells which present members of small free lengths and great depths and result in high resistance to bending and buckling.

Structural stiffness can therefore be obtained without serious effects on cost by suitably designed shapes and sizes of the structures in question. Reduction of inaccuracies of manufacture, and correction of alignment errors due to initial play or wear of bearings and slideways can, however, be effected only at considerable expense. The permissible limits at present in use would have to be tightened considerably in order to match the accuracies obtainable by electronic measuring and control equipment, and much more maintenance work would be required than is the usual practice today.

The frequencies of alignment variation of an amplitude of the order of 0.0001 in. to 0.001 in. due to such errors are not likely to be very high, and instead of increasing manufacture and maintenance cost it would appear more economical to measure such alignment errors as they occur and to make use of the accurate control equipment provided (see Section **(c)**) for superimposing error compensating movements on to the feed motions normally required. Such error correction devices would consist of optical or electrical measuring and control equipment.

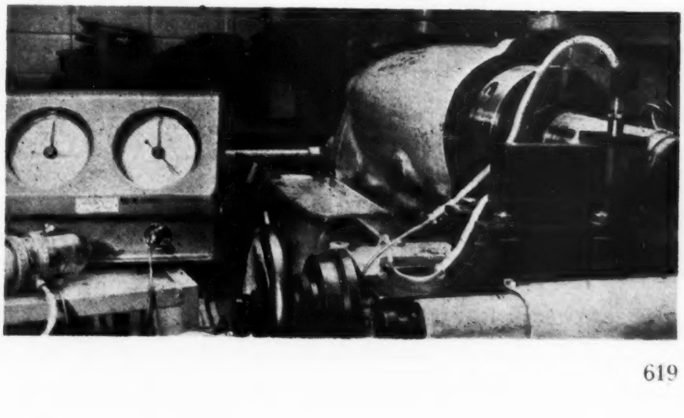


Fig. 7. Two-dimensional dynamometer equipped with pneumatic gauging equipment (developed by Dr. W. B. Heginbotham).

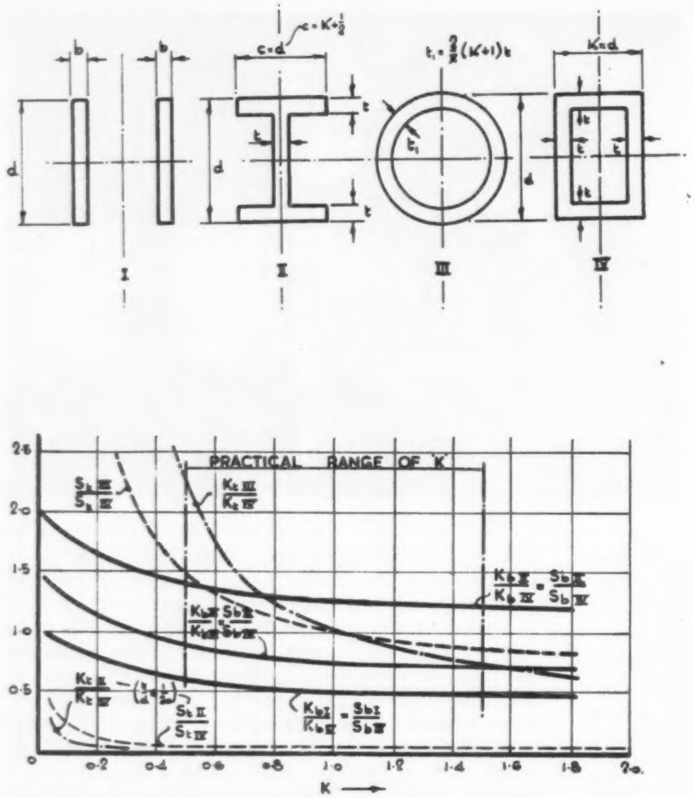


Fig. 8. Bending and torsion characteristics of four typical sections.

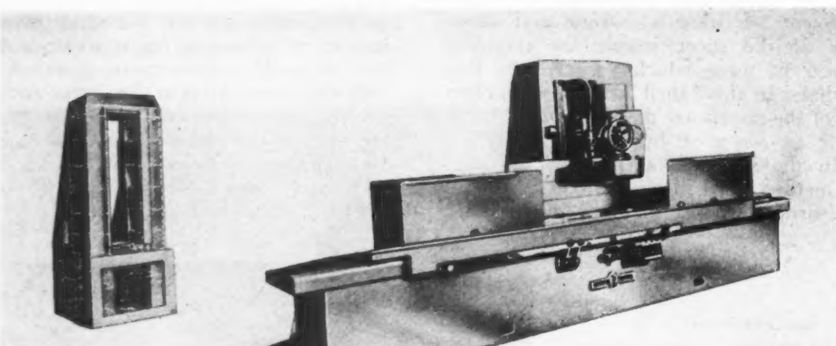


Fig. 9. Surface grinding machine in lightweight welded construction with the cellular construction of the upright shown schematically on the left ("Diskus", Germany).

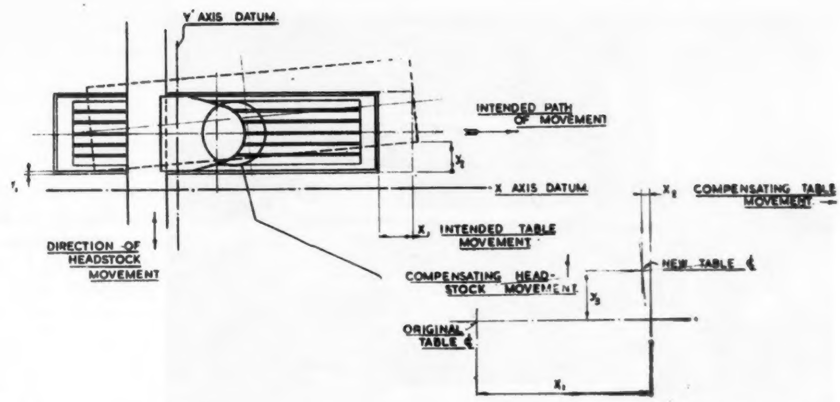


Fig. 10. Principle of error correction.

Errors of alignment and of wear cause lateral or angular displacements, i.e. displacements in directions different from those of the actual setting and feed movements. They cannot, therefore, be covered by the equipment which measures the position of spindle head stocks and slides in the direction of their operational movements.

It is proposed to relate the alignment of such parts to datum lines or datum faces on components which are not subjected to any load. For the example of a table and a spindle head stock, which are to be moved or positioned along two ordinates at right-angles (Fig. 10), the datum lines may be represented by straight edges of high accuracy arranged parallel to the operational movements of the parts in question. Any lateral displacement or yaw of the moving parts can be measured in relation to these datum faces.

If during a required operational table movement of amount x_1 in the direction of the x-axis a lateral table displacement (y_1, y_2, as indicated by the dotted line) occurs and is measured, this can be compensated by an appropriate movement y_3 of the head stock and an additional movement x_2 of the table itself.

Similar corrections can, of course, be applied to three-dimensional work and to possible displacements of the spindle in its bearings. This may necessitate rotational as well as rectilinear movements of the parts in question and will have to be studied, once the basic two-dimensional problem has been solved.

The practical execution of this idea is a combined electronic and mechanical problem. It covers measurement, computation and control and is at present under investigation.

(c) operational feed control

The operational movements of a metal cutting machine tool are :-

1. The cutting movement, i.e. the relative movement between the workpiece material and the cutting edge of the tool, which results in the cutting action and is usually produced by the rotation of the main spindle (except in the cases of planing, shaping or broaching machines). Stiffness and dynamic stability as well as good frictional characteristics reducing power losses are important, and the developments in this field cover air and oil pressure lubricated bearings aiming at a combination of smooth running conditions with a high degree of accuracy.
2. Once the cutting movement is available the control of the working speed and accuracy of the machine is concentrated on the setting and feed movements which determine the relative positions between tool and workpiece at any moment of the operation. This may be demonstrated for the example of a table drive for a two-dimensional profile milling machine. Apart from the machine structure itself the elements which affect the performance of the drive are :
   (a) the system of sliding parts (for the case of the example, the table moving on its slideways along the x-axis);
   (b) the driving gear for the feed movement;
   (c) the mechanism for initiating and transmitting the control impulses to the feed drive gear.

In (a) the slideways guide the moving parts along their required path. They must provide alignment and location under the working load, but they must not be over-determined. The smaller the number of constraints, the more positively can the mode of strain transmission be determined. Furthermore, over-determination means expensive fitting operations and may exert restraint in case of expansion or contraction due to change in temperature. The application of pure kinematic design principles such as three-point location would appear theoretically desirable. It is, however, practically inadvisable because of the resulting high specific pressures. The use of a cylinder and flat arrangement is being investigated, and in order to overcome the limitation of length set by possible sag or deflection of a cylindrical guide supported only at its ends (Fig. 11) an arrangement is proposed which incorporates a cylindrical guide supported over its full length (Fig. 12(a)). It is important, however, to realise the difficulties encountered in manufacturing a slotted cylinder of considerable length within the required limits of circularity and cylindricity.

The properties of the sliding faces and their lubrication influence the frictional resistance in the

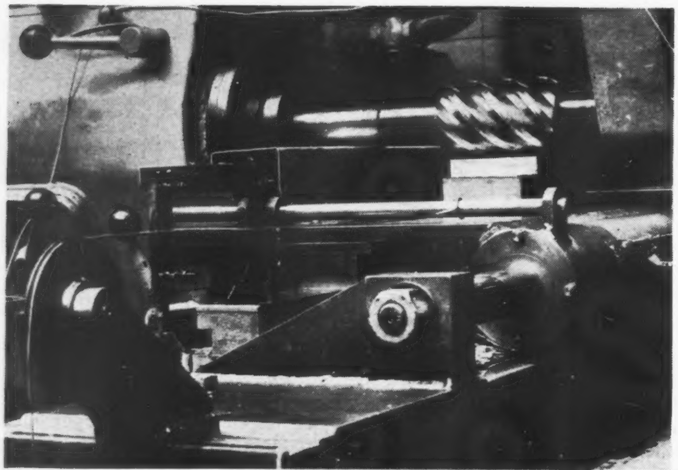


Fig. 11. Slideway test rig (plain slides mounted on a horizontal milling machine).

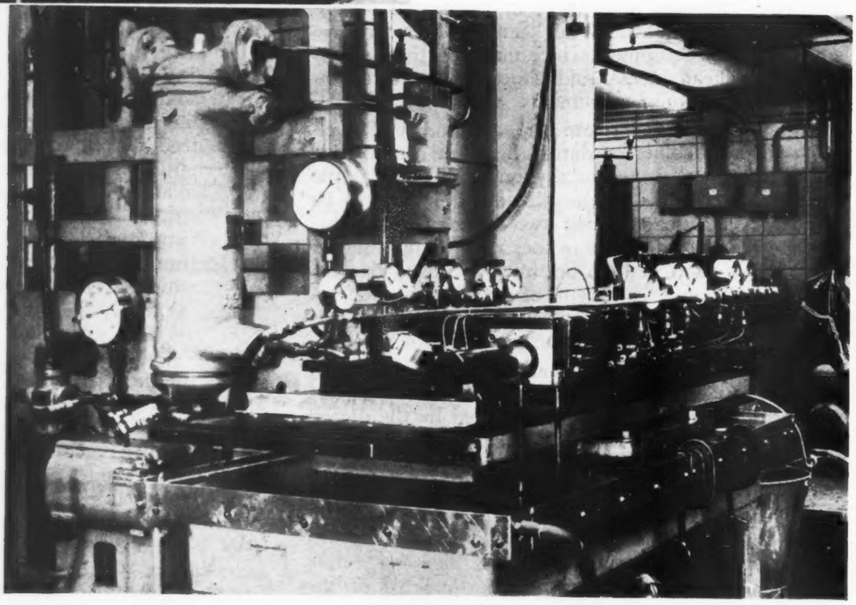
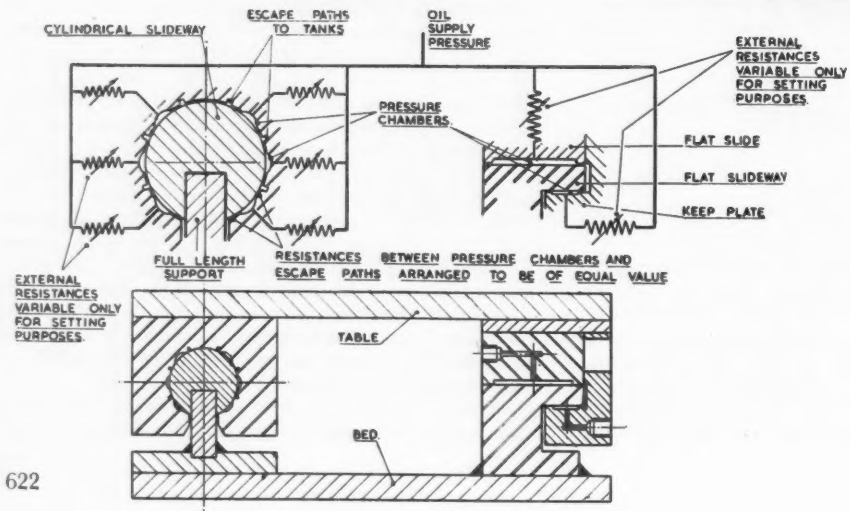


Fig. 12. Slideway test rig (pressure balanced arrangement): Right (a) general view ; Below (b) principle of operation.



slideways. Viscous friction is often desirable because of its damping effect on the slide movements. A high coefficient of static friction, however, decreasing with velocity — "stick-slip" phenomenon — makes the precision control of slide positioning and moving usually extremely difficult if not impossible, and is one of the causes of "judder" at creep speeds.

Attempts should therefore be directed towards reducing or eliminating stick-slip phenomena, although viscous friction and its beneficial damping effect will usually have to be reduced at the same time.

When precision ball or roller slides are used, it is necessary to make certain that under the point or line contact conditions specific pressures do not become excessive, and that at the extremely low frictional resistance values the small forces exerted by roller cage chain links and ball tracks do not cause considerable variation of the forces which resist the movement of the moving parts thus introducing an element of inconsistency.

In a well-known large horizontal boring machine, steps have been taken to float the moving column on a pressurised oil film. This appears satisfactory for such a large machine, where the weight of the moving part will always be greater than the highest operational forces which may tend to lift it off its oil bearing. The magnitude of the cutting forces acting on a horizontal borer is so small, compared with the weight of the column, that the variation of oil film thickness under the changing load (weight of column ± cutting force) is apparently negligible. On small machine tools this may not always be the case, and an arrangement of pressure balanced bearings * is now being investigated. This is not merely a theoretical problem as the questions of accuracy and clearance values which determine the oil film thickness, affect the manufacturing and running costs of the bearing. Fig. 13 shows how clearances affect the oil film stiffness and the volume of oil which has to be delivered to the bearing. Small clearances mean greater accuracy requirements and therefore higher manufacturing cost, whilst an increase of the oil volume requires more expensive plant such as larger tanks, larger pumps, filters and oil coolers. A test rig for a pressure balanced cylinder-and-flat slideway arrangement is shown in Figs. 12(a) and 12(b).

The first investigations into plain slide bearings on the slideway test rig (Fig. 11) were carried out by applying to the slide a constant moving force in the form of dead weights (Fig. 14). The position of force application and the load on the slide were varied, and the coefficients of static and sliding friction determined at different slide velocities.

Fig. 15 shows the results of such tests. Before the moving force was applied the slide was given time to settle in its starting position. Tests with settling times of 0, 5, 10, 30, 60 and 120 seconds showed that above a velocity of about 6 in. per second the frictional coefficients converge towards a value which is independent of the settling time and predictable to within ± 5%.

The order in which the tests were undertaken is shown on the graph. All tests were completed within about three hours. There is an overall trend throughout the order of the six tests for the values of the coefficient of friction to drop. This shows that the settling time influences the coefficient of sliding friction as it also influences the coefficient of static friction. Although the sequence in which the tests were conducted may conceal an influence of the "warming-up" effect upon a reduction of the frictional coefficient the general trend remains clearly visible.

As would be expected the maximum value of coefficient of static friction is greater than that of sliding friction after movement. Where only short settling times were allowed, i.e. 0.5 seconds, the opposite effect was observed. This is due to the reduced settling time resulting in lower values of static friction, because the oil film has not been squeezed out.

The sliding friction coefficient will rarely rise above the static coefficient at the usual feed rates encountered in machine tools (below 6 in./second).

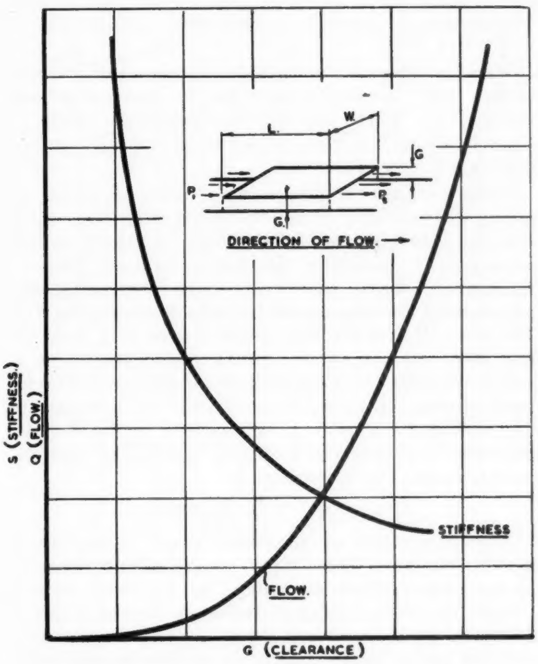


Fig. 13. Stiffness and oil flow plotted against clearance in a plain slideway bearing.

The stiffness is calculated for the case of a certain constant flow as: $S=\left(\frac{3}{2K}\,Q\nu L^2\right)\frac{1}{G^4}$ (lb./in.) where ν = kinematic viscosity;

The flow is:

$$Q = K\,\frac{(P_1-P_2)G^3W}{\nu L}\ \text{(in.}^3\text{/min}$$

* This principle has been successfully employed in the machine, Fig. 1 (Patent Application, J. Gregson and A. Flett, The Fairey Aviation Company Limited, Stockport).

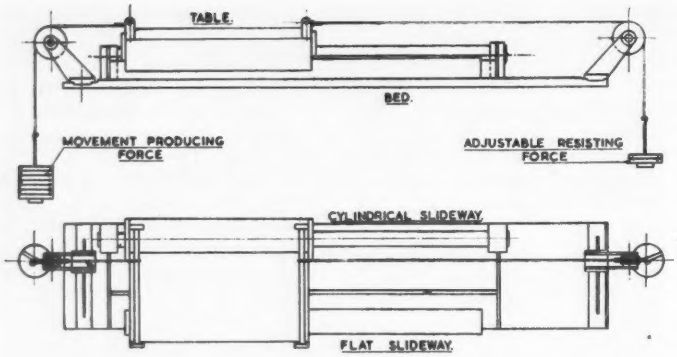


Fig. 14. Arrangement of plain slideway test rig.

However, the negative damping at low velocities (the cause of stiction) can be clearly seen in the graph.

When point (b) is considered it is seen that the driving gear for the feed movement has to overcome the frictional resistance in the slideways, the inertia of the moving masses and the forces exerted at the cutting edge during the cutting process.

Steady and accurate movement, especially during reversing, is only possible if backlash in the driving mechanism is either eliminated or rendered ineffective.

Various devices for backlash elimination in lead screws were developed in order to make machines suitable for down cut milling operations. Most of these resulted, however, in increased pressures on the lead screw thread.

Two methods of design have been proposed to satisfy the performance requirements. The first, which may be called a load relief device, is based on the principle of providing the forces required from a hydraulic cylinder and ram whilst controlling the accuracy of the movement by a lead screw (Fig. 16). The load (P_s) on the lead screw is kept at a constant low value by means of a strain gauge arrangement acting through a transducer and operating a hydraulic valve device which in turn controls the pressure in the cylinder in such a manner as to make the difference between the hydraulic load (P_H) and the cutting load (P_c) a constant :-

$$P_H - P_c = P_s = \text{const.}$$

The movement of the lead screw is controlled by the magnetic tape input and the measurement of the table position by optical or electronic means.

Another design which is being developed employs a worm and rack feed-drive which continuously resets a short stroke hydraulic piston for precision positioning (Fig. 17).

This equipment, at present under test, has a high degree of stiffness, which makes it possible to take advantage of recent developments in high performance hydraulic flow valves. The frequency and phase characteristics of these valves are such as to enable the gain of the servo to be high consistent with stability, and high gain ultimately means greater accuracy.

High stiffness is also beneficial in cases when stick-slip cannot be avoided and when the driving mechanism is strained while the parts to be moved remain stationary. As soon as the stored strain energy is capable of overcoming the stiction resistance, sliding begins, the stiction resistance drops, and the strain energy is released. This will cause a jerking movement, often beyond the required position, and if this is corrected by the servo-mechanism, hunting will occur. The stiffer the driving mechanism the smaller will be the strain caused by the resisting forces and the displacement due to the release of the strain energy.

Now consider point (c). The mechanism for initiating and transmitting the control impulses to the feed drive gear comprises :-

1. the equipment providing the input information (e.g. from a punched or magnetic tape);
2. the equipment measuring the position of the moving parts (e.g. diffraction grating or inductosyn equipment);
3. the devices translating the differences between 1 and 2 into control impulses for 4;
4. the electrical or hydraulic equipment which actually operates the driving gear, e.g. electric motors and their control gear, hydraulic valves, etc.

The design of this equipment presents electrical and mechanical servo-mechanism problems, which have to be solved with reference to the specifications mentioned before, and which concern servo performance in general and the performance of electronic devices and hydraulic valves in particular. They do not fall within the scope of this Paper, but form, of course, part of the work on the project which is at present in progress at The Manchester College of Science and Technology.

Machine tool engineers in all parts of the world are aware of the new challenge, of the great opportunities offered by electronic control equipment and of the need for making full use of them. Development work in this field is known to be actively caried out in the United States, in Western Europe, and behind the Iron Curtain.

Only by combining the efforts of research workers, of design as well as production engineers and of the

Fig. 15. Test results concerning the coefficient of friction as a function of sliding velocity obtained on the plain slideway test rig.

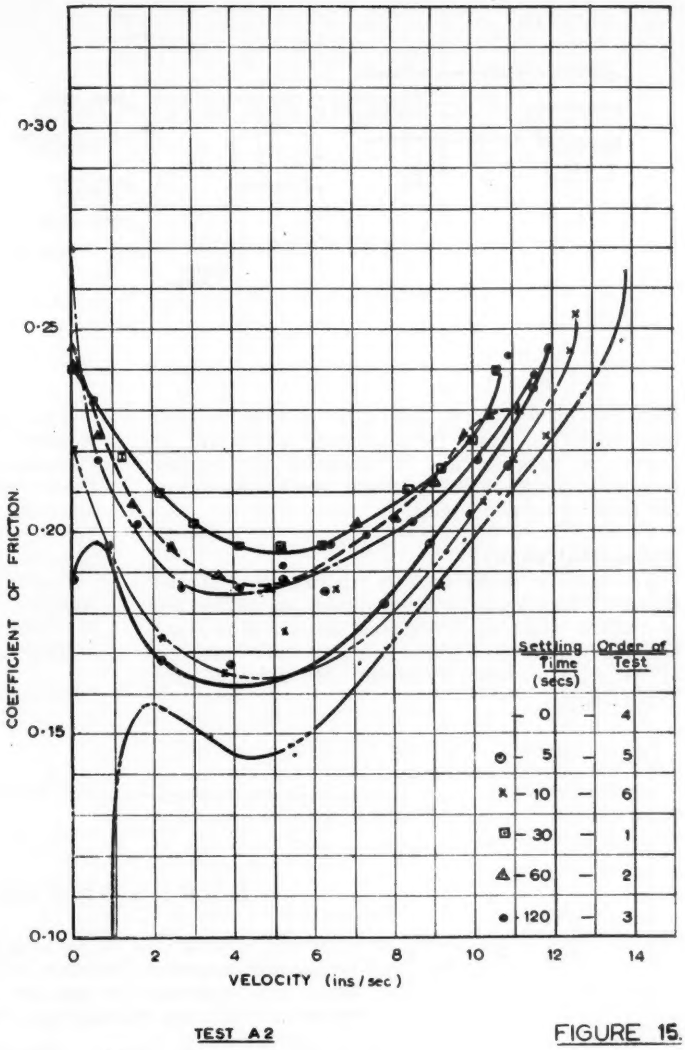
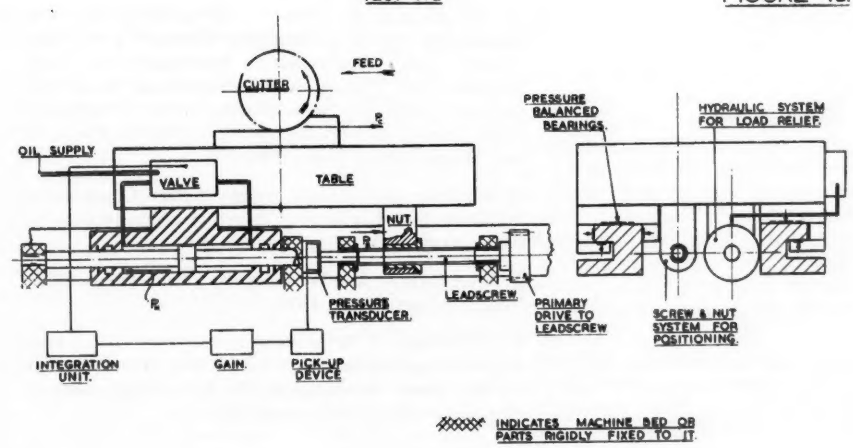


Fig. 16. Feed drive with load relief device.



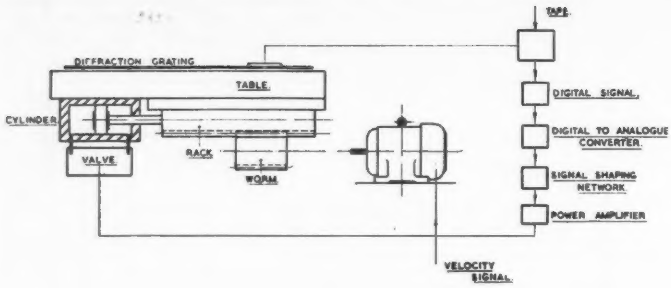


Fig. 17. Feed drive combining long stroke worm and rack arrangement and short stroke hydraulic piston for precision positioning.

industries behind them, will it be possible to keep pace with the rapid developments which are at present in progress, and to maintain the leading position in the machine tool world which this country has held for so many years.

Acknowledgments

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Finally, the author would like to thank The Fairey Aviation Company Limited, Stockport, for providing the illustration of their three-dimensional profile milling machine.

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REPORT AND DISCUSSION

Chairman :

John Mitford Brice, M.I.Prod.E.,

Technical and Commercial Manager, Rockwell Machine Tool Co. Ltd.

THE **Chairman** said that during the last few years many people, even those outside the electronics industry, had learned something about electronics and its application to machine tools. Many Papers had been given on electronics and related subjects at conferences organised by the Institution and other bodies. Those dealing with machine tool applications had always shown the need for a very much closer co-operation between the designer of electronics equipment and the machine tool designer.

It was therefore pleasant to have Dr. Koenigsberger at the present Conference and he had pleasure in inviting him to present his Paper.

Dr. F. Koenigsberger in presenting his Paper, which appears on pages 610 - 626, said :

I am a lecturer at a University and I have therefore acquired a certain amount of a schoolmasterish attitude towards things. For this reason, being also rather optimistic, I assume that a number of you — I should not like to say how many — have read the Paper. Those who have not done their homework will perhaps do it during the lecture or afterwards, for I feel that it would be better for me to tell you the ideas behind and around the Paper, emphasising the points which I consider important, rather than to read what you can read, and perhaps have read, for yourselves.

For that reason I should like to begin by giving you an idea of what the Paper intends to do and what it is not intended to cover. The subject of the Conference—' Production Fights Inflation '—should be behind any Paper given here.

Inflation has been described as a state of affairs in which too much money chases too few goods. It would be difficult for anybody, even a production engineer or a machine tool designer, however clever, to attempt to reduce the amount of money available, but it is possible for him to produce more goods in a shorter time and at lower cost.

The influence of the machine tool on the productivity of a manufacturing plant is affected by the quality and the quantity of its output. An increase in quantity—a larger number of components produced within a given time—is useful only if the quality is such as to make possible their easy incorporation into larger units—in other words, if interchangeable assembly can be ensured.

This is already important in manually operated machine tools, but the performance of automatic machine tools has to be carefully considered from the very first step in the design stage. The design of such machines thus ceases to be a matter of applying nothing more than skill and experience in handling cutting tools in order to create machines which can locate, clamp and guide a tool and a workpiece. In other words, design by trial and error has to be replaced by analytical investigation and synthetic development.

For many years the need for a scientific approach to the problems involved has been stressed, and some outstanding publications have appeared with the aim—as put by one author—of securing for the study of machine tools a place in the sun among the recognised sciences.

the practical approach

This is all well and good, but a machine tool designer who cannot base his design on the experience of something similar which has been done before must have an imaginative approach to the problem. While his head may be in the clouds, his feet must be firmly on the ground and the practical approach must not be neglected.

When the possibility developed of applying the potentialities of electronics, specialised control equipment, servo control devices, etc., to metal cutting and machine tool operation, the field, already wide, increased to such an extent that the machine tool engineer had to enrol the help of the electronics engineer, the servo control expert and others in order to bear in mind all relevant points of view. In specialised industrial development, however, there is a danger of each specialist pushing his own subject forward and possibly forgetting the overall importance of the ultimate project.

Electronic engineers may consider an automatic machine tool nothing but a specialised application of electronic control equipment, while servo control specialists may look on a machine tool as a large servo mechanism with some tools and some workpieces attached to it.

I remember recently meeting a medical man who talked about a brilliant dental surgeon whose operations, according to medical people—tastes vary—were worth seeing. They spoke of the elegance with which he performed his operations and the complete absence of any traces of his work on the jaw when he had finished. The jaw looked almost as new. The trouble was that this dental surgeon very often overlooked the fact that attached to the jaw on which he was operating was a human being. The patient might finish with a jaw without any scars but his cheek might have been cut open to permit access to the jaw, leaving a scar visible for many years. Thus, the dental surgeon carried out his own specialised work but forgot the ultimate object of a human being who wanted to be healthy and good-looking.

This danger exists in the machine tool industry if the electrical engineers, the servo mechanism experts and others are left to do everything and to forget that the ultimate objective of a machine tool is the efficient production of the components at a reasonable speed and at an economic cost.

the main purpose

The aim of the present Paper is to show how in modern machine tool design the various specialised and highly important aspects have to be correlated and centred round the main purpose—the development of a machine which will produce workpieces of a specified quality at the required speed of output and at a competitive cost. The Paper does not, therefore—and that is quite intentional—deal with details of servo problems nor does it discuss electronic circuits for measuring or controlling operations as such.

A further reason for these things being left out is that I am mainly a machine tool engineer and I know only a limited amount about these things. My colleagues, who have helped me very much with the Paper, are the experts on the detailed subjects. My job is to correlate their work with the ultimate view in mind of looking after the finished machine tool and its elements.

For this reason an attempt has been made in the Paper to describe the basic principles which have to be considered for the machine tool as a whole. A machine tool designer used to designing certain types of machines and with great experience has all the details at his finger tips, but when you come to something new you must give yourself a clear picture of the specifications and detailed problems involved. I refer to such details as the forces and velocities acting at the cutting edge, their effect on the power requirements, on the accuracy and the speed of production, and consequently on the design solutions for the various elements of the machine.

Graphical representations of the power conditions have been developed. Those in the Paper may frighten you, but they look much more difficult than they are. The nomograms in the Paper are not intended to enable designers to use them directly as they are, but to show how similar ones can be developed for any particular application, and how otherwise cumbersome lengthy calculations can be simplified by the use of nomograms suitably designed at the right scale and size. The calculations are not difficult, but if you have to do them several times at several combinations, it takes time. The nomograms thus save time and you get good results. The value of the nomograms lies less in their accuracy than in the fact that the designer can see clearly the trends in changing force, speed and power conditions through varying his parameters. For instance, you may find that if you vary one parameter little happens, but if you vary two you may be fortunate enough to get beneficial results in a third.

In order to carry out the required calculations, some basic information on desirable or recommended speeds and feeds and the resulting force parameters is necessary. In the nomograms this information is indicated by heavy lines, which are plotted for an aluminium alloy and for mild steel in the case of the centre lathe, and for mild steel only in the case of the milling machine. It may also be mentioned that the cutting speeds plotted on the lathe nomogram are based on a tool life of 240 minutes for tungsten carbide tools (suffix 1) and 60 minutes for high speed steel tools (suffix 2).

The information on recommended cutting speeds and specific cutting pressures had to be taken from sources published abroad, as unfortunately no definite and authoritative recommendations of this kind could be traced in British publications. This should not be taken as a criticism but rather as a challenge, and every attempt should be made in this country to fill this gap. This does not mean merely that cutting forces must be measured in various research laboratories or tool life tests carried out. All that has been done here as well as, if not better than, elsewhere. But it requires the co-operation of research workers, machine shop engineers and machine tool designers to establish a final authoritative recommendation.

Recommendations have to be established which are the result of thorough research work and of sound experience in successful workshop practice, thus combining information based on technical facts and on economic possibilities and necessities. Such a recommendation would say that if you want to use a tool for 240 minutes for an up-to-date job you must not use a speed above a certain value under the given conditions.

precise power determination

The need for precise power determination increases with growing power requirements. It is all well and good to make 100% contingency allowance if an operation requires, say, three horsepower, so that with a six horsepower motor the designer is safe from unpleasant surprises. But one of the features of electronics is that there is not only one brain and two eyes and two hands; you can do things simultaneously which a manual operator cannot carry out. When motor requirements, or power requirements, are of a magnitude of 50 horsepower such contingency allowances are highly uneconomical.

The problem of machining quality has been given attention for many years. It combines requirements of design, manufacture and operation of the machine.

Static stiffness, behaviour under pulsating loads and under vibration conditions—free, forced or self-excited—create problems which the designer has to solve before the manufacturing engineer can start to produce the various parts of the machine tool within the required limits. This cannot be decided on ordinary workshop acceptance tests.

lightweight construction

In the Paper I have referred to the use of lightweight welded construction which has been applied very successfully for certain machines. One well-known machine is a surface grinder about 5 ft. long and 15 in. wide, which has been successfully produced for about 25 years. The body of the machine is built in 4 m.m. steel, about $\frac{5}{32}$ in. The machine has been designed and built in Germany, but the lightweight construction developed there has not been much used elsewhere, because the economic conditions in various countries have a very important bearing on the decisions which a designer may take in using certain methods.

As an example, in Germany the cost of one ton of mild steel is approximately the equivalent of the cost—labour plus overheads—of 80 man hours. Thus the saving of one ton of steel in a machine structure is an economical proposition, as long as less than 80 additional man hours are required for the fabrication of the structure in question. Corresponding figures in this country and the United States are reported to be as low as 50 and 20 man hours approximately, and it is, therefore, much more difficult to save weight in a welded steel construction with a corresponding increase in labour without increasing the overall cost of the product.

With the requirements of non-selective interchangeable production and the possibilities of precision measurements offered by electronic devices, the problems of manufacturing and assembling the parts of machine tools increase, and some suggestions have been put forward in the Paper by which the electronic means of precision measurement and control can be used to make up for the practical limitations of precision manufacture and operation, such as machining and aligning tolerances, wear of slideways and bearings and cost of manufacture.

There should be little need for increasing the accuracy of manufacture to uneconomical proportions. One can still use the machine as it stands and obtain the highest precision and accuracy provided by the electronic control means. It is proposed that the alignment of the various parts should be related to datum lines or datum faces located on parts, which are not subjected to working load, of the machine, to measure lateral or angular displacements of the moving parts and to compensate for these displacements by appropriate movements of corresponding sliding parts of the machine. We let the machine slide move within the inaccuracies with which it normally moves, and we then correct for these inaccuracies by letting the other slides make up for the error.

The precision initiation and control of operational movements of the various parts in question depends to a great extent on the sliding resistance and the driving mechanisms. The elimination of friction in slideways appears to be an important factor, even if the damping effect of viscous friction may be reduced at the same time. The experimental work described in the Paper in connection with slideways is proceeding and it is hoped that definite design specifications will be available in due course. At the moment I can give only the principles and the ideas.

With regard to the feed drive it is essential to provide large forces which, at the same time, must be controllable within a high degree of sensitivity. Two solutions have been mentioned. The first incorporates a load relief device in which the pressure on the metering lead screw is kept at a constant low value, the power being supplied by hydraulic pressure. This kind of device is limited in its application for various reasons. One important reason is the length of stroke, because for long stroke mechanisms the stiffness may decrease and the resonance frequencies may become difficult to control unless the whole layout is adequately designed. For this reason the second device is being developed which appears to eliminate the difficulties of the first. The disadvantages of the hydraulic cylinder and piston, when applied to long stroke operations, can be overcome if the long stroke is covered by a coarse driving mechanism such as a worm and rack, which is not very sensitive to length of stroke. This is used to reset continuously to its central position a short stroke hydraulic piston which deals with the precision positioning of the moving part. There is now a short column of oil with a high natural frequency, high stiffness and highly sensitive to high precision control impulses. As soon as the hydraulic piston starts to move out of its position, the coarse drive mechanism will put it back into the central position.

a brief survey

I have not tried to cover all aspects of the problem but have tried to show you some of the ways in which we are tackling it in Manchester. We are fully aware that many other aspects should be tackled, too, but these are the problems which I think are of particular interest and importance.

It will be appreciated that the Paper is but a brief survey of some aspects of an extremely wide and complex field of machine design, but it is hoped that it will provide some food for thought and thus help in stimulating work which will help to make machine tools play their part in fighting inflation.

The Chairman asked Dr. Koenigsberger to enlarge on his description of the hydraulic cylinder mentioned towards the end of the Paper, and the coarse rack and pinion or worm and rack drive to reset the hydraulic cylinder.

Dr. Koenigsberger, in reply, said that the illustration was schematic and one could write a whole Paper on this subject alone, but he would illustrate the principle on the blackboard. In the case of a milling machine table covering one or two movements, there was a tape control which contained the information on where the table ought to be at a certain moment. A measuring device told the servo mechanism where the table actually was at this moment and the servo mechanism had to put the position right.

The valves were operated electrically and the piston was attached to the rack which was driven by the worm, the cylinder being attached to the table. The oil was led into the cylinder on the correct side and the piston, being held by the worm, was stationary while the cylinder moved, let it be assumed, to the left. The table was thus beginning to move to the left in accordance with instructions. If nothing happened to the rack and worm, the cylinder would continue to move to the left and the cylinder wall would hit the piston, which was undesirable. As soon as the cylinder had covered a certain stroke relative to the piston, the motor started driving the rack and the table would continue to move until the measuring device told the servo mechanism that the correct position had been reached.

The rack drive was fairly coarse and might drive the rack too fast or too slowly, but that did not matter. If it went too fast, for example, the hydraulic cylinder would immediately hold back. On the other hand, if it went too slowly the hydraulic cylinder would tell the motor to go more quickly. In other words, the motor would try all the time to keep the piston central in the cylinder. When for some reason or another a position was reached in which the motor overshot or undershot, the piston would always hold the table exactly in the correct position.

Mr. Mills (*De Havilland Propellers*) said the author had spoken about a coarse mechanism with the implication that it was a rough mechanism, whereas in fact it had to be as precise as any other part of the machine. All that one did with the small hydraulic cylinder was to reduce or increase the stiffness of the overall system, and the coarse system must be designed to be completely backlash-free and completely stiff. He thought it debatable whether they could get greater stiffness with the gear drive than with a simplified, long-stroke piston.

Had any thought been given to fluid to a higher modulus than normal hydraulic fluid in order to work at higher pressures? He believed that if they worked normal fluids below 1,000 lb./in.^{2} they had a very low modulus. Moreover, in a system above 1,000 lb./in.^{2} they could get greater stiffness. He knew of no machine tools at present which worked in a pressurised manner.

Dr. Koenigsberger replied that they were experimenting with the mechanism and he could give no figures, but Mr. Mills was quite right in saying that the mechanism which had been described as coarse was not a second-rate or low-quality mechanism. It had to be backlash-free and stiff. The worm and rack used were irreversible and backlash-free. Heavy hydraulic pressure was available and the worm was held closely meshed into the rack. The worm itself must have no backlash in its thrust bearings, and this was eliminated by hydraulic pressure. The mechanism must be smooth. The term " coarse " gave the impression of a hand-filed worm and rack, but he wanted to dispel that impression immediately.

He recalled an example in his own workshop experience in which he had sketched roughly some mechanism for a prototype design and handed it to the fabricating shop to weld together. In return, he was given a piece of mechanism in which every lug and every bearing was between ½ in. and ¾ in. out of alignment. When he complained, the foreman said, " You gave us a rough sketch, so we gave you a rough job." He did not want to give the impression, therefore, that the worm and rack in this case were a bad mechanism. It was coarse only in as far as the precision control need not be of the same degree as that for the cylinder and piston.

Mr. Mills, taking up the phrase " not of the same degree ", asked whether it must have the same stiffness.

Dr. Koenigsberger said that it must have the same stiffness. He added that the piston stroke was such that, even assuming it was only 1 in., any errors within 1 in. in rack and worm mechanism would be compensated all the time by the hydraulic system.

Mr. Jones (*Hilger and Watts*) asked the speaker to elaborate on his comment about the slideways.

Dr. Koenigsberger, in reply, referred to the photograph of the Fairey machine in Fig. 1. He said that a pressure balanced slideway bearing was used in it, successfully. His job in this research project and development work was not to design a finished machine tool; he was not in competition with the machine tool industry. His purpose was to investigate the various qualities and to establish design principles of elements of machine tools. When they were successful they would hand these over to the machine tool industry.

The Fairey machine, in which this type of lubrication was used, worked satisfactorily, but the difference between the author's work and that of the machine tool manufacturer and designer was that the latter wanted to sell his machine, designed a prototype to the best of his ability, built it and then started to make it work. The author, on the other hand, wanted to investigate not only whether a design worked but what were its optimum conditions technically and economically.

This was why the pressure balance arrangement was investigated, in order to see how the stiffness was affected by clearances and by precision manufacture. They had started with a very fine finish and a high degree of surface finish on the slideways, with very fine clearances giving minimum oil flow and maximum stiffness. Having established these conditions they would then increase their clearances and roughen the surfaces, in accordance with the old principle that you should not build a machine as good as humanly possible but as bad as the job would stand it. The machine had to be satisfactory, but there was no need to go to perfection for perfection's sake.

Another problem which had to be investigated was that of ball and roller slides. Only a few tests had yet been conducted.

Another possibility, which he had mentioned in the Paper, was that of pressurised hydrostatic lubrication. There existed the case of the very heavy moving column of a large horizontal boring machine being floated on a pressurised oil film. This was perfectly satisfactory and he had seen the machine working. With a heavy column of five or six tons, the cutting forces—the pulsations varied between 100, 200 and 300 lb.—would be only 1% of the total pressure on the slideways. A smaller machine might, however, weigh much less and the cutting load might be 8 cwt. to 10 cwt. Thinking in terms of a weight of 5 cwt. and a pressure variation of 100/200%—there might be displacement of the table, which might not be permissible or justifiable. Consequently, the pressure balance arrangement appeared to be advantageous, but it was being placed under investigation after preliminary investigations had been made on ordinary, conventional, orthodox slideways which were lubricated by an operator putting in a drop of oil somewhere and hoping for the best! It was clear that such an investigation was needed and would be useful.

Mr. Crane (*Ministry of Supply*) asked the speaker for his opinion on the long-term stability of welded structures in machines. He had in mind the movement of a machine from one place to another.

Dr. Koenigsberger replied that this was a very controversial subject. The dimensional stability of welded machine tools was a very important matter and it could be completely controlled by design and by treatment during manufacture. They knew that even castings were not perfectly stable after manufacture; indeed, many of them would agree with him when he said that if they did not treat the castings they could have some very unpleasant surprises.

One main reason for dimensional instability was the residual stresses which were set up in welding and which could be reduced, first, by suitable welding procedures. In spite of the welding procedure, however, they could not eliminate such stresses entirely because they could not over-simplify the machine tool structure, which was usually complicated in the first place.

The first mistake which the designer could make was to take the design of a cast machine, place a piece of tracing paper over it, trace it and then replace all the radii by welds. That was the best way of making welded construction a failure. It was essential to consider the whole problem differently, to forget all we knew about cast structures.

The first welded machine tool structure which he had had to design was designed in Italy in 1936. Out of a batch of ten machines, one casting cracked. Foundry deliveries then being bad, it was impossible to obtain a replacement quickly; out of the batch of ten machines, nine would have been available and the tenth would have arrived six months later.

It was therefore decided, at the risk of failure, to try a welded bed. He had studied the whole question theoretically rather than practically before this, and on this occasion he did his calculations very thoroughly. He had been anxious not to make any mistakes in the design of the bed. Eventually, he discovered that the wall thickness had to be about ¼ in.

Having drawn it and looked at it on the drawing board, he was, however, scared. With his present knowledge he realised that this structure would have been perfectly satisfactory and would have done the job as well as any other, but at that time, having never seen a welded machine tool structure and having been accustomed to castings, he thought that the drawing looked quite horrifying and, without telling anybody about it, he increased the thickness to $\frac{3}{8}$ in.! This still looked dangerous, but he felt that he owed it to his own pride not to go too far! As it was, he put in fact a 50% contingency allowance on the job. The job turned out to be perfectly satisfactory, but he was now convinced that the $\frac{1}{4}$ in. wall thickness would have been enough.

An important point to bear in mind was that permissible stresses and elastic limits were so much higher, and any steel structure—thinking in terms of beams and cantilevers—should be deeper and shorter than the corresponding cast structure. If thinner plate materials were used, the residual stresses were already going down because the material would yield more easily under welding expansion and contraction. It was necessary to heat treat the structure afterwards, however, and the heat treatment consisted of heating it to 600–650° C for a normal structure, and up to 720° C for high precision machine structures. The latter temperature was slightly above the lower critical point of the material and this might reduce the impact resistance of the material. This did not matter because the stresses in a machine tool were very low in any case. He had worked out the stresses in a conventional lathe bed and had found them to be about 120 lb./in.^{2}. Even if these were raised to 250 lb./in.^{2} there was nothing to worry about.

One secret about heat treatment was that the structure had to be left in the furnace until every part had reached the stress relieving temperature, and that the furnace doors were kept closed after the heat had been switched off until the temperature had dropped below a certain figure. That was the most important point of all. For the ordinary machine structure he suggested going down to 300° C; indeed, he would not allow the doors to be opened above 250° C and for high precision machine tools he would even suggest 150° C.

Possibly the audience would be more convinced by practical results than by pure theoretical considerations. He would therefore explain that he had used this procedure successfully on high precision structures.

This heat treatment was unpopular because a long wait for the next batch was involved in keeping the furnace doors closed while the temperature fell from 720° C to 150° C; the curve flattened out at 250° C and the drop from 250° C to 150° C might take twenty hours.

In one case where this treatment had been carried out clock gauges and other measuring instruments had been placed on a welded fixture at strategic positions, but with the equipment then at his disposal—in 1947— he had been unable to detect movement, even though a hole 1 in. × 5 in. diameter had been bored in a solid block. The fixture was measured again after six months in the workshop, and again there had been no movement.

The Chairman asked the speaker to comment on the ability of such a lightweight structure, as opposed to a casting, to absorb vibration. There was a feeling that a heavy lump of cast iron would absorb vibrations whereas an equally strong welded structure would not.

Dr. Koenigsberger replied that the main feature of cast iron, apart from the mass, was that it had inherently a higher vibration damping capacity. The theory was that in cast iron there were fine needles of free graphite which caused mechanical friction within the material, and this damped any vibrations which might develop. These needles of fine graphite did not exist in steel. According to some investigators, these graphite needles were also the reason for the lower Young's modulus of cast iron. Graphite did not add to the stiffness of a structure; one had in fact a structure with little holes.

The damping property of cast iron was certainly higher than that of steel, but it was possible by suitable design to make up for that and to introduce damping into welded structures. One suggested method was to create artificial pre-loading by flanging pieces in positions of high shear strain where rubbing took place. Experiments had shown that the damping property of a welded structure could thus be increased forty or fifty-fold. Even after ten million cycles of vibration no change in the damping could be detected.

A number of problems were involved—corrosion might take place—but the fact remained that the damping could be brought up to the required magnitude. Other points which should be considered included the lightweight construction. The natural frequency of a structure was proportional to the square root of the stiffness over the mass. If the stiffness could be increased with the same mass or the stiffness maintained with the lower mass, the natural frequency was raised and the whole structure might be removed from the danger of resonance vibration. The only danger with the lightweight construction was that of large overall sections and very small wall thickness. The normal stiffness of the section as a whole was increased, but the stiffness of each panel was considerably decreased.

It was necessary to find a compromise. This was where increased labour costs were involved. The panels had to be stiffened individually, which used additional labour, but the saving in material in grinding machines, for instance, compared with cast machines using the same design was about 45%; the machines weighed 55% of cast machines. The reduction in cost was about 25%. Thus, there was some disadvantage; it was not all saving, because extra labour and overheads were involved.

He quoted the example of a machine which had been measured after two years in an aircraft production workshop during the War. He reminded the meeting of a well-known saying about sub-contractors to the main aircraft companies during the War: " Give us the jobs and we will finish the tools." In spite of this, the machine in question had been found satisfactory in accordance with the normal acceptance tests. There might have been some differences, but none could be found by the normal standard workshop equipment used, apart from wear on a slideway or the corner of a table broken off because somebody had dropped a heavy fixture on it. In other words, after two years' work under severe conditions, the alignment of the machine and its dimensional stability had not suffered. In that case both the welding and the heat treatment procedure had of course been carefully watched.

Mr. Crane asked whether a jig boring machine could be built of welded structure.

Dr. Koenigsberger, in reply, said that he knew of at least one jig boring machine which had been built in welded construction and which had been very successful. The first sale might not be indicative of success, but if people bought a second machine it indicated that it was at least not too bad.

The design and manufacture of jig borers was highly skilled and required much experience. He would not expect any designer in a company of repute making jig borers to risk his and the company's reputation by an experiment, when he could do the job satisfactorily in a proved manner. The job of the designer-pioneer in this field was dangerous and the expense involved in trying the new method might not be worthwhile, unless the person concerned was starting from scratch and had to build up his experience. Leading firms in the field had developed heat treatment procedures for castings and other parts and they could hardly be expected to drop all that and to do something entirely different, at the risk of having teething troubles. It was possible to do this but it was difficult unless one could afford to experiment for some years.

Mr. Mills asked the speaker to summarise the features which were most important in the design of a machine tool for this class of work by automatic control. Probably machine stiffness was the first feature—overall stiffness from the tool to the machine. They could either have a stiff machine tool working to data off the slideway, or they could have a springy tool and work to the size of the workpiece. In a hand operated lathe there was only the stiffness of the body, but they could produce to fine limits because they put calipers on the job. The second feature was a stiff drive and more fundamental ways of measuring what they were making, with perhaps a change from normal methods of measuring.

Dr. Koenigsberger replied that with the ideal feedback control mechanism it ought to be possible to have a machine of no stiffness—a very thin machine—with the tool moving around in thin air, as long as the feedback mechanism could always position the tool in the right position relative to the workpiece.

That was perhaps the ideal; it would make machine tools very much lighter than they were now, but it would make the measuring devices and the tool holding devices much more difficult to design.

It appeared to be a more economical approach to the problem to reduce the functions of the electronic device and the servo mechanisms to that work which could not be dealt with by mechanical stiffness and strength of the machine. Stiffness of the spindle drive would be needed. It was very difficult to provide a servo mechanism which would compensate for vibrations of a frequency equal to that which might be encountered. There might be high frequencies even in steady operations. In some measurements in turning brass, the steadiest operation of all, frequencies of 6,000 cycles per second had been observed. These were not often of high amplitude, but they were high frequencies.

With a milling operation, running at a cutting velocity of 10,000 feet per minute, with a cutter of 6-in. diameter, they had about 6,000 revolutions per minute. If the cutter had four teeth, this meant 24,000 impacts per minute or 400 per second. It was difficult to design a servo which would have a response of this magnitude.

It was therefore advisable to design the machine so that it was stiff enough to deal with anything which could be dealt with by any machine mechanically designed in a sound manner.

The second feature was stiffness and stability of the drive, and for instance, fly wheels on a milling spindle designed to avoid oscillations. Stiffness of the feed drive was also needed.

Next, they needed co-ordination. With a static positioning device it did not matter, within reason, when one slide, moving along the ordinate, appeared at a certain point in relation to the other slide. If they bored a hole in a jig borer at positions X and Y, the table could be moved to X and the spindle headstock need not arrive at Y until 10 seconds later. Only at the moment when the tool began to work both had to be in the right position. On the other hand, with profiling, longitudinal and cross traverse must arrive at X and Y simultaneously. It was important to have co-ordination and a faster response of the whole drive to the impulses of the control device. Stiffness in that drive was important to avoid displacement and errors and to avoid frequency oscillations at high frequencies which would affect the surface finish.

The third feature was the provision of power. There was little point in doing a job by electronic control unless you could work faster. You could not use a milling cutter above a certain speed because of the effect on tool life and you could not use speeds where the feed arrangements were excessive because of the possible effect on the surface. Productivity must therefore be increased by carrying out several operations simultaneously, which meant higher power requirements. It must also be possible to enable the machines to take higher loads without trouble. Other problems were stiction, precision in manufacture or control and error correction by means of electronic measurement devices.

Mr. Mills said he had hoped that the author would mention a fundamental change in their thoughts about measuring on a lathe. If they wished to take .001 in. off a workpiece, they moved the tool in .001 in. The tool holder was moved .001 in.

Dr. Koenigsberger replied that this point was mentioned in the Paper. The tendency in jig borer design had been not to combine driving and measuring devices. The size of the workpiece or the positioning of various parts was used rather than the movement of the driving mechanism. It would be best to measure the workpiece rather than the table in order to cover any distortion of the workpiece. He had given much thought to this but had not yet decided how to do it with profile milling; it was a very difficult job. It would be ideal to measure on the workpiece, as it had been done on cylindrical grinding. It could be done on turning, but the main point was to dissociate the drive mechanism from the measuring mechanism.

Mr. Brewer (*Imperial College of Science*) said he was surprised that the distinction between positional control and continuous contour control had arisen so late in the discussion and that its implications had been neglected. The speaker had said that it had a profound effect upon the philosophy in designing a machine. With continuous contour control there was the difficulty of maintaining the same relatively high order of accuracy for a continuous part, and this prevented the use of one or two devices which had been suggested for simple positional control.

The principal idea on which he wanted Dr. Koenigsberger's view was that of changing the conception of the machine table and considering it as a structure. He was speaking here in terms of mechanisms. It was not completely free but was treated as a free body until it was near the position, when it became effectively clamped and use was made of very small movements to achieve final accuracy.

One method which had been suggested for these small movements was magneto-stiction. Another method was to induce stresses in the connecting link by either force or thermal application, although this had disadvantages and drawbacks from a practical point of view. He knew of only one practical application of the first method, and that was not on a machine tool.

Would the speaker comment on the use of this method for positional control? Obviously it was not available for continuous contour control, but there they had a slight advantage in that they were not dealing with movement at very slow speeds. In addition, on the continuous contour side they had the interpolation system and the true path system. The interpolation systems, either linear or parabolic, approximated to the continuous curve by a series of small segments. These never produced exactly what was wanted and the degree of refinement used was an influencing factor in anything decided about the drive.

The Chairman said they must keep the two things separate. One was positioning control and the other was profiling, and they were different programmes.

Dr. Koenigsberger, in reply, said the fact that the discussion on the separation of the two control systems had arisen so late was not his fault; he had stressed the point in the Paper.

Positional control, as such, was perhaps only one step towards the fully automatic machine tool for automatic control. Taking some of the best-known machines working on such principles, they had an operator who could press a button or a punched card to set the table or the headstock slide in position. When that had happened there was a green light, the operator pressed another button and the boring operation proceeded. This could be combined, and instead of a green light they could have a relay which started the operation automatically. But these were more or less sequences of impulses going on rather than continuous automatic control, and in the Paper he had tried to stick to continuous control.

There were certain points in relation to position control which might be of interest. One device which was used slowed down as it approached the job. This was purely an electronics problem.

Up to a point the same situation applied to interpolation. There was no point in trying to design a machine which was more accurate than the accuracy which could be obtained from the computer. He had no experience of magnetic stiction, but he understood that a company in America was using it in the " Inch Worm " device.

Although they would not like the spindle headstock to arrive one hour after the table in the correct position, nobody would worry about a delay of 1/10th second in static position control, but the situation was quite different in a profiling machine. They could not slow down one slide without correspondingly slowing down the other; the whole operation was slowed at the same time. Consequently, they had to consider the possible effect on surface finish when suddenly changing the feed rate; there might be a change in surface finish.

If there were changes in the cutting load, the driving mechanism must ensure that there was no slowing down. This might be a matter of hydraulics. It could be done, but it was more difficult than in a case where one could accelerate and decelerate at will for each separate mechanism without having to fear the consequences.

One method of determining a position was to set a micrometer screw to the required accuracy and then to move towards it. The only criticism of the method was so slight as to be almost theoretical. It was that they were still measuring the rotation of a screw which might wear.

All this was impossible in the continuous drive arrangement. The introduction of stresses into the structure might lead to unpleasant consequences. Clamping in position—unless there were position control—and the tightening and loosening of clamps might not be a good thing. It could be used to increase damping, but there were other and better ways of damping the movement of a slide than by increasing and decreasing friction.

unless one could control it to such an extent as to be certain that whatever happened one could always come back to the intended conditions.

This was an entirely different problem, and he had tried to report on the work he was doing and to stick to the problem of continuous control.

Mr. Brewer, referring to the "Inch Worm" system, said that the only application of which he knew was not to a machine tool but to a positioning table, but there was an obvious application to a positioning system. Normally the table was driven by lead screw and nut. In this case when they were near the position, the table and the rigid part of the machine base were joined by a link. For general purposes they would regard the table as fixed to the main part of the machine, but obviously that link possessed some elasticity and the application of a reasonable force to it would cause it to extend by perhaps .0001 in. or even .001 in.

The principle was to induce very small extensions in the link so that the table moved relative to the machine itself. The point was that this was something which could not be prevented by any form of stick slip. If a stress of a certain magnitude were induced in this link, it was compelled to move by a certain distance, coupled with the elasticity, and the only thing that could prevent it would be the application of a greater force. As the stresses involved would be thousands of pounds per square inch, nothing of the normal frictional force would have any effect. The introduction of stresses by purely mechanical or by thermal means was very doubtful.

There was the possibility of making use of the electrical or electro-magnetic phenomena of magneto-stiction whereby, through magnetic means, they could make material expand or contract by a small amount. That was the practical way in which this was done. It had been patented as the "Inch Worm" system, and although he had studied thirty positional control systems he knew of no one who had made use of it in the positional control system. It might be that there were practical difficulties which prevented its utilisation.

Dr. J. K. Royle (*Manchester College of Science and Technology*) said that stiffness had been mentioned in two contexts—the stiffness of the machine tool itself and the relationship to the surface finish and stiffness in relation to the driving mechanism. What they were seeking in automatic profiling machines was an extremely high degree of accuracy of the finished workpiece. One needed a first-class control system to overcome the difficulties which had been discussed, both in pure positional control, where time did not matter, and in the continuous and accurate control of position under dynamic conditions. In order to provide suitable servo mechanisms which would produce sufficient accuracy of the finished workpiece, a stiff drive was essential. The stiffness of the drive was the effective limiting term on any servo system.

This was one of the basic reasons for using the short-stroke hydraulic ram, and it raised the question of the compressibility and pressurisation of oil. Compared with steel, oil was very compressible. It was essential to use short-stroke rams at high pressure and to take advantage of some of the extremely fine performances now available with hydraulic belt systems. When one reached the two to three horsepower level of the driving system, hydraulics showed considerable advantages over similar electrical methods. Did the speaker agree that stiffness had to be related strictly to the machine tool aspect, from the point of view of economics and surface finish, and also, quite distinctly, to the servo aspect?

Dr. Koenigsberger replied that he was in complete agreement with Dr. Royle. Dr. Royle had been his adviser and had done much work on hydraulics. There had been no controversy between them, even behind the scenes!

The Chairman, concluding the discussion, said that if production engineers were to get more productivity out of their machines, they would be helped by the work being undertaken in Manchester. The companies concerned would be pleased to receive basic guidance on machine design so that machine tools could be successfully and efficiently used with modern electronic equipment, which in the last few years had grown, had become simpler and, at least in application, had become more easily understandable to the average machine tool designer.

Dr. Koenigsberger had said that the time would come when this would be made available to the industry through various channels, and that was of great importance. Equally important was the work which Dr. Koenigsberger was doing—not only the basic scientific work, but the co-operation which had been achieved between the machine tool designer and the companies manufacturing electrical equipment. Very little co-operation had existed in the past, but it was now growing, and one of the places where it was fostered was the University of Manchester.

He thanked the speaker for his interesting Paper and for having answered the questions so ably.

The vote of thanks was accorded with acclamation and the proceedings terminated.

JOURNAL BINDERS

The increased size of the Journal has made impractical the present type of binder, and as a result of requests from members, the Institution is now arranging to supply the "Easibind" type of binder, in which metal rods and wires hold the issues in place, and which is designed to hold six Journals.

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Cybernetics Operational Research and Automation

by F. H. George, Ph.D., M.A., F.R.S.S.

A Paper presented at the Production Conference, Olympia, on 15th May, 1958.

Dr. George, who is Lecturer in the Department of Psychology at the University of Bristol, was educated at Taunton School and Sidney Sussex College, Cambridge, where he read Moral Sciences and Mathematical Triposes.

He gained his B.A. at Cambridge in 1948 and his M.A. in 1952 and, also in 1952, gained a Ph.D. for work on mathematical and logical models and their applications in learning theory.

He was Visiting Professor at Princeton University, U.S.A., in 1953 - 1954, and carried out research at McGill University, Canada, in 1953. His principal interests are now in experimental phychology, mathematical logic and philosophy of science, and the synthesis of these three disciplines in cybernetics.

MY plan is to try to set out a clear and general picture of what cybernetics and operational research are about, and then to indicate their relation to automation. As far as automation is concerned, I hope to show that there is a great need to understand the fundamental principles on which all automatic control is based, since it represents a very general scientific methodology with far-reaching consequences; a failure to understand these principles is the surest guarantee of a failure in application. However, I wish to make my appeal to practical people who are primarily interested in production on the factory floor or in other everyday circumstances, where elaborate theories, in themselves, are not enough and so I hope to dwell on examples that have a practical and intuitive appeal ; this fact prohibits the possibility of careful proof, although such a proof of most of my statements, I will claim, is always available; and where we are explicitly conjecturing I shall note this as a matter that requires either proof or practical demonstration.

Cybernetics is a general name for the study of all control and communication systems. Therefore, if I study computers, either analogue or digital, because I think I see in them the hope of an analogue to human behaviour, then I am indulging in cybernetics. If I build a special purpose computer as an analogy to any process whatever, I might also be said to be dealing with cybernetics; it is clear that there are no precise limits to the subject; it cuts across all the conventional boundaries and includes engineering, mathematics, biology, psychology, and so on and so forth. So I may be within the scope of cybernetics if

I simply sit down and work out mathematical equations and descriptions. However, there are certain salient features of cybernetics; the first is the idea of control being automatic and being primarily a process of *negative feedback*; secondly, there is the idea that systems may have the same properties, whether they be organic and called "living", or inorganic and what we normally tend to call "machines".

Operational research is in many ways more vaguely defined in its limits than cybernetics and certainly something that cuts across it, and might even, in a sense, be said to include it. It involves primarily the application of a strict scientific procedure to all problems, and specialised because it supplies the characteristic model-theory treatment of science, to situations which do not already come within an accepted branch of science. In brief, operational research represents the application of scientific method to everything and anything; we must say something, then, about scientific method.

Automation, which we will come to last of all, is applied cybernetics, and perhaps something that generally goes hand in hand with operational research.

I would like to emphasise that there is no special reason at the moment for trying to use these three names in a precise way, since they are commonly used to cover whole sets of ideas, concepts, and operations, so let me rather try and indicate their breadth and importance. It is in this respect that I expect automation — in view of its great publicity — is already well-known, and needs less explanation than cybernetics and operational research.

Scientific method

I must now turn to a description of scientific method; what a scientist normally employs. Naturally there is still some dispute about these matters, and I will try and give an outline in terms that will emphasise those parts on which we should all agree, since for practical applications, fine differences, about such things as the metaphysical background, for example, I shall assume make no difference at this stage of *application*.

Perhaps I can best illustrate what scientists do by listing the characteristic steps they follow, and the findings which they derive from these steps.

It is known that science depends on observation. We have to be able to observe things, whether directly or indirectly. To do this we may use microscopes or telescopes to improve our range of observation, but we still have to have direct contact with certain states of certain systems.

From these observations, generalisations are made which can be put in the form of axioms or postulates that can subsequently be used for deriving consequences and so allow prediction. The step from particular observations to guessing at the generalisation is called the *inductive* step. This step may be taken on a number of different grounds ranging from sheer guesswork, where no evidence or justification can be adduced in support of the hypotheses or generalisation, to good evidence based on a number of careful observations. We might see a red apple, and then another red apple, and then another, and might reasonably say "I believe all apples are red", and since we mean this to be a statement that is empirical and capable of being tested (by observation) we must go ahead and see whether or not all apples are red. If not, then our generalisation is false, although if *almost* all are red, we might state a weaker, statistical, generalisation; "nearly all apples are red". We shall, of course, be careful here to notice that its redness cannot be a defining characteristic of an apple, otherwise there is no need to test our statement; it would be true by definition and everything that looked like an apple and was, in fact, green would have to be called a "bapple" or "gapple" or something else.

Having achieved a set of statements that are well-confirmed (to which we have not observed any exception), then we may deduce particular consequences. That is "If all apples are red, then if you have an apple in your pocket, it is necessarily red". So, roughly speaking, the scientific method is made up of the two processes of induction and deduction, fitted together. These processes link the two operations of testing, which depend on observation and include careful scientific experiment, with that of generalising, where the generalisations are sometimes called hypotheses (if highly confirmed, laws) that follow from accurate observation statements.

Probability and statistics

In our search for models, both in specialised sciences and now in any situation where the scientific method will be employed, we shall find ourselves using probability theory and statistical methods based upon probability. These can be used in two different ways which we should distinguish.

The Laplacian theory is the probability theory most easily applied. This says that the probability favourable to some specified event A is given by ratio of the number of ways which the favourable event A can occur to the total number of ways that the event can occur at all. To take the simplest sort of example, we shall say that the probability of throwing an even number, with one throw of an ordinary die is $\frac{1}{2}$, since there are three ways of the favourable event occurring: we may throw 2, 4 or 6, and there are six ways in all that the event can occur: 1, 2, 3, 4, 5, or 6, and therefore the Laplacian probability gives $3/6$ or $\frac{1}{2}$.

We can now consider sets of events with which we can associate probabilities in *a priori* fashion. Alternatively, we can count the number of occurrences of events and make some prediction on the basis of what we count. Thus if we wish to know whether height and weight are highly correlated in any group, we can take a random sample of the group and calculate a *correlation coefficient*. We could then calculate a correlation coefficient for another group under the same circumstances and we can compare one group with the other. These methods require careful application, the use of control groups, proper methods of sampling and the careful consideration of many other factors besides. This use of statistics allows us to carry out an extended reasoning process

about groups of things or people, with some degree of probability. We can by such methods make deductions and therefore predictions.

The second way in which probability will enter our considerations is where we use it to describe some system. The probabilities arise either because the system is too large to handle any other way — this will frequently occur in industrial problems — or where we do not know all the necessary facts in advance of our computation. This is characteristic of induction, and also of the human being in the data-processing which we associate with the activity of the human brain.

It is because of these two factors that many of our models — the symbolic and abstract models used in operational research — are of a probabilistic or statistical kind. We shall be referring from time to time to the specialised statistical methods which we shall continually meet throughout the application of cybernetics and operational research to industrial problems, both at the machine level and at the broader organisation levels.

So much for our summary of scientific method as it seems to operate and, of course, ignoring all the various complications in designing experiments and the full methodology, involving detailed statistical applications and so on and so forth.

Language and logic

We can now regard this scientific method a little more carefully as a relation between ordinary statements, in English or French or any other everyday language, and their underlying logical structure. Since the structural relation between precise statements is very important, it will often involve the use of logical or mathematical models, or even physical models, with specific geometrical properties. All informal descriptions of scientific phenomena are approximate and convenient, but sometimes too vague, and we may then expect to have to go over to a more precise, although equivalent, description. This sort of thing can be exemplified by the difference between an informal description of a scientific system and a mathematical description, or the difference between a rough description of a machine and a detailed and precise one. We shall say about this that we have a model of our ordinary language and this may be a precise linguistic or logical model, or it may be a physical model, like a wind-tunnel is a physical model of the aerodynamic characteristics of certain aircraft. These models can be regarded as analogues of systems and if we build a model first we can observe the characteristics of the model without having to build the full-scale system. This last idea stands at the very base of operational research and the link with scientific method is immediate, since it is directly derived from the methodology of science.

The first part of our description of scientific method is primarily concerned with cybernetics, since whereas we can normally build a machine to perform the deductive operations, an inductive one has been more difficult to build. However, there is now some reason to believe that a digital computer can be programmed to perform both inductively and deductively, where its normal use in computation and control is deductive, so the model we need of a physical system may be in the form of an analogue computer. As a result, in automation it is perhaps digital computers and digital methods that more and more offer the best control facilities, and with inductive programming there seems no limit to what can be computer-controlled; and the systems controlled will involve those other stand-bys, servo-systems and their chief realisation in the form of analogue computers.

Theoretical consequences of cybernetics

We should perhaps mention, before we get to the real problems of practical interest, a few general points about the scientific and theoretical background of this work on cybernetics and operational research.

In the first place, mathematicians and other scientists have spent a great deal of their time studying languages and games. The reason for this is simple. In language we find the usual communication problems which play a vital part in every aspect of our lives. In games we find characteristic social situations and problems arising, and they, of course, depend upon language. We must learn the rules of the games, and then the tactics, and this is exactly the way in which we organise any enterprise whatever, and should not be regarded as an amusing but irrelevant study by mathematicians who live many floors up the Ivory Tower.

There has been developed a branch of mathematics — very much a branch of probability, like Information Theory—wherein games of chance are analysed, with respect to, say, our economic behaviour, although again the model used can be applied, or extended, to cover any sort of situation whatever. From this point of view science can be regarded as a game against nature, and various optimal tactics have been worked out for the playing of such a game. These we would automatically use whenever we started to apply operational research, or our learning programmes, to actual industrial situations. Similarly, science can be regarded from the point of view of translation of the coded language of nature, where we seek to discover the rules of the language and then apply the rules deductively. These two applications are of fundamental importance to cybernetics and operational research.

We shall mention an interesting result derived from mathematical logic which shows that any game — such as chess or draughts or noughts-and-crosses — if it must be completed in a finite number of moves, these must be capable of having a deductive procedure. Logicians have called this a *decision procedure*; which means that there is a book of rules that says exactly how you should proceed to play the game and never lose. Games are not limited in interest since we can regard almost anything as a game, and we know now that if it is also finite it can be "machine played" — since this is surely the correct interpretation to place on the idea of playing from a book of rules.

If we accept this criterion and agree that a deductive process is certainly one that we might expect to

reproduce in a machinelike process, we shall not mean to imply that those processes that are not capable of being so mirrored are not capable of such a machine interpretation.

Indeed, the history of automatic control systems and their application, suggests that we normally try and reduce what is primarily an inductive process — something for which no rule book exists — to a deductive process, so that we only have to build a deductive system to carry out the necessary operation. This does not, of course, bring out the other feature of the operation, which is that, however complex the process, it must be capable of being reduced to a series of simple steps. This is, in fact, a necessary condition both for automatic control systems and also for the ability to perform automatic computations as they are carried out by the computer.

Cybernetics will go ahead and define all systems — whether organic or otherwise — in terms of the models and theories which can be supplied for its predictive description, and from this point of view, it is claimed that living and non-living systems are not essentially different. They both involve communication and control; where to control a system, the possibility of communicating in the form of observing the existing state of affairs, and sending out a controlling message to change (if necessary) that state of affairs. Here we tend to emphasise that cybernetics is capable of supplying predictive models for the biological sciences, and we can leave it at that, except to add that much time and effort has been spent in this direction in building models and theories which are effective in reproducing every sort of empirical situation.

Our last word on the theory of the subject is to the effect that certain specific techniques have proved very useful in our process of scientific model-making. We might mention such developments as information theory — which is the general theory of communication between any two points whatever. Also stochastic processes, and particularly Markoff processes, which are the forms of statistical analysis that are most closely related to the description of empirical situations involving human and other inductive systems. In this context we might mention mathematics generally and mathematical logic in particular, and perhaps Theory of Games and abstract algebra.

Stochastic models

Briefly, let us show a stochastic model and its importance. Consider a language which has only three symbols and here we choose such a language for the sake of simplicity. We could, as does the computer, use a language with only two symbols, or English which has 27, allowing one punctuation symbol.

If our alphabet is made up of just three symbols A, B and C, say, then any sequence of symbols :

ABBACCBBABCBACAA

is a stochastic process, and we may associate a probability with each letter. If each has a probability of $\frac{1}{3}$, then the three letters will tend to occur equally often.

Now a Markoff process is a stochastic process where the probability of occurrence of one letter is conditional on the probability of the letter that occurred immediately before. So for the table :

	A	B	C
A	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$
B	1	0	0
C	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$

we may expect, starting with A, to find sequences like :

AAABAABAAACAACCBABAAAC

where the occurrence of the letter is dependent on the letter immediately before. If the source emitting these letters is said to be *ergodic*, then we shall expect a degree of homogeneity and series of letters will tend to repeat themselves. Indeed, we can build machinery that operates on these principles. Furthermore, we should regard a machine that operated in such Markoff process terms, where the probabilities in the table changed with experience (by keeping a count) as a learning machine, and exactly what our learning programme aims to copy.

Machine translation of language obviously fits in with these sort of models, and science generally fits in if we regard nature as an ergodic source.

This aspect of our subject links up with information theory and whole ramifications which we have no time to discuss, but whose applications are only just beginning.

This must suffice for a summary of the vast theoretical background to our problems, now to their most general practical application and some of their consequences.

Science in action

Perhaps we can divide the practical applications into three categories :-

1. the engineering category with all the attendant difficulties of planning a factory at the floor level;
2. the problem of organisation at *all* the various levels at which it occurs — this is probably the most important of all current cybernetic and operational research applications;
3. the industrial psychological problem involving human relations ; can we expect to create circumstances where a worker will get as much pleasure from doing his job as he does from playing his games, and if so how ?

The first question is that of equipment. Our modern factory installs machines to improve the efficiency of the muscular output of man, and this it has done for years. It results in increased production, and increased efficiency in the sense of an article produced more economically.

As far as the equipment problem is concerned, it is fairly well-known that one of our biggest current problems is in fitting the appropriate control to the mechanical system that is to be controlled. This problem has been brought into high relief by the fact that mechanical and control engineering have

largely developed on separate lines. The problem of finding the suitable machine to control is largely a problem for engineers, and our only comment on this will be to the effect that we must remember to analyse exactly what it is that we are hoping to produce or achieve, and to remember that we may be able to achieve the desired end with a wholly different form of apparatus from that which we have conventionally used. This problem has two sorts of consequences to which we should draw attention.

We may undertake to build an automatic control system to replace a human operator pilot; for example, we might proceed to build a system that simply does the work of the human pilot in his context as a pilot, therefore omitting many other abilities that he may have which do not bear on his flying skill. But further consideration will persuade us that this is where we need to rethink — in the words of John Diebold — the problem; it would, in fact, be grossly uneconomical to approach it by direct substitution of control. In the first place, the layout of the cockpit of an aircraft is explicitly designed around the human operator, with dials and pointer readings that appeal to the human eye, and controls that are designed for human arms and legs. These dials and controls are only specified ways of observing and changing the state of certain systems, such as the engines and their speed, and various engine states. This suggests that we shall, for our new automatic control, feed information about the different systems directly into control and make our modifications by linkages which are suitable to our servos, or computers controlling the changes.

One important point emerges from this and that is that we have come to regard certain systems as being conveniently observed in terms of certain characteristics that lend themselves to easy representation on dials, whereas we might now consider whether we cannot discover new and perhaps better indices of the states of our various systems. The pilot's eye scanning the surface of an aircraft will discover a fire after it has broken out; could we not find some index of the occurrence *in the future* of combustion and make direct use of such an index (such work has in fact already been carried out) ? All this implies the development of new technological methods that will accompany, and even make possible, the machinery of the future, where such machinery will be designed in terms of the control systems on which it will operate.

As for control, we see already that digital methods, so successful in mathematical computations, have been developed to deal with mechanical outputs as well as mathematical ones. We see this emphasised in many new developments; among those best known are the Ferranti and EMI computer-controlled cutting machines. Analogue systems have, of course, also played a large part in such control.

In terms of what we said earlier about inductive and deductive systems, it seems that existing digital control methods are normally deductive *in their use*. We should lay heavy emphasis on the fact that this does not *need* to be the case, since a computer is not a fully defined machine without its programme, and experiments are now going forward on the use of inductive programmes which should prove of the utmost value in the future. The idea underlying this development can be described briefly.

Computers

A computer normally follows explicitly the instructions that are put into its storage and these instructions are followed regardless of what particular numbers occur in the storage. With an inductive system, we shall let the instructions vary according to the nature of the inputs that subsequently occur. To draw the analogy with ordinary human behaviour we should want to say that the input was coming into the system all the time. In practice, we shall use the computer inductively wherever this situation is unavoidable. This reminds us that the uncertainty occurs under these circumstances precisely because we do not know in advance what is to occur in the input. We can reduce this case to the more unnatural case where the numbers may be stored and then operated upon in some order, and the instructions modified in the light of the items on which the instructions operate.

More specifically, we shall have in our programme to specify certain designated input letters, so that the occurrence of these designated inputs serve to reinforce or inhibit the combination of inputs that it follows.

Then for the instructions to modify themselves in the light of "experience", we must cater for the classification of information in storage so that the inductive and deductive consequences, as well as other patterns and relations bearing on what is stored, can lead to new generalisations (i.e. instructions).

The detailed problems of the inductive machine, and actual programmes that have been developed, by myself and my colleagues at Bristol, and similar programmes, particularly on many-valued logical programmes, by Professor Porter and his associates at the Imperial College in London, will lead to new special purpose computers, new programmes for general purpose computers, as well as the development of new digital, analogue and digital-analogue methods.

We should notice in passing that this is a matter that is of as much interest to the biologist and the psychologist as to the production engineer, striving as he is to fight the economic problems of inflation, by the systematic applications of the unlimited resources of scientific endeavour.

Logical nets

I wish now to outline a special set of models which I have myself played some part in developing, and which I believe may be of special use, ultimately in supplying a universal language in which to construct verbal models; because we must remember that models are not to be thought of only in hardware but also as abstract sets of symbols — indeed, anything at all that can be given an interpretation or made isomorphic with a system that we wish to

describe or study. From this point of view, we would, for example, distinguish between marks on paper such as 0, 1, 2, . . . , + . —, and so on, and the interpretation that we place on these symbols as the familiar operations of arithmetic, and we call them "zero", "one", "two", . . . , "plus", "minus" and so on accordingly. Normally we do not bother to make this distinction between the concept and the *name* of some symbols which refers to the concept, but it is this distinction that is necessary to the precise use of models and language — which we could regard as models for our thought — in science.

We have now developed such a model for all possible computers and we should state straight away that in this respect it is slightly different from an earlier method for all computers by Turing. Turing constructed a theoretical machine which has since been called a Turing Machine and which was made up of a potentially infinite tape marked off into squares, with symbols $S_0, S_1, \ldots, S_n$ that are written on the tape, and the scanning and writing device that makes up the rest of the machine. It is capable of overprinting, moving to the left one square, to the right one square or stopping. The machine can be said to be in any number of different states, for which we use the symbols $q_1, q_2, \ldots, q_m$ and then a particular Turing Machine is defined by a set of quadruples, which are four symbols such as $S_1 q_k \rightarrow S_k$ and which says "when the machine is in state q_k scanning symbols S_1 it will move one step to the right on the tape and scan symbol S_k which is the next symbol printed on the tape".

With only four different such instructions and some special conventions for the input and output of numbers, such a theoretical computer can deal with any problem that can be handled by the full deductive use of any computer.

It was in terms of the Turing Machine that Turing himself was able to show the class of mathematical problems that were solvable or computable by the most obvious of "machinelike" methods. Perhaps the most curious thing about his machine was the fact that he was able to show that it had great generality, and that any other machine that could be designed for such computations was capable of being reduced to a computing machine of the Turing type. This is very much the same situation as with models of computations in terms of many-valued functions. It can be shown that there is no loss of generality in considering only binary functions, since all problems involving more than binary functions can be shown to be reducible to the binary form.

Turing Machines can be called infinite or potentially infinite automata. I will now turn to our more central case of finite automata. A particular form of finite automaton — another theoretical machine — can be described as follows.

The elements of the system are the basic building blocks and these elements are connected to each other by lines that are divided up into input and output lines, where by convention we draw our diagrams showing elements as circles and input lines on the left and output lines on the right. There are two different sorts of possible input lines which we call excitatory and inhibitory, and these tend to excite or stimulate on one hand, and inhibit the element on the other. There is only one output line which may divide into a number of different lines going to any number of different elements, but all must be in the same state at any instant: either carrying an impulse or not carrying an impulse. Now each element has a number associated with it and this measures the sensitivity of the element and says just what the preponderance of live excitatory inputs must be over live inhibitory inputs to fire the element in question.

Now we can divide our elements into three different classes, those that occur, conventionally, on the left of our diagram and without elements attached to their input wires — called input elements; those at their right-hand end and without elements attached to the output wires and called output elements; and the remainder which we call inner elements. These sets of elements taken together we call a network or net and it can, of course, be regarded as a model of a computer. We have described our computer in binary terms, without, as we have already said, any loss of generality.

With these theoretical computers we can investigate the properties that any computer, or any control system whatever, may have. We can show, for example, the process of input, output, storage and arithmetical operations that make up the ordinary digital computer.

We can show simple properties of association in a net where messages can become associated with other messages in such a way that a message originally having a particular effect, now has a different sort of effect, or a new message takes on the same effect as an older message.

In short, we can reconstruct all the characteristics of deductive machines and envisage principles such that any type of control can be investigated. However, this is not the main interest that attaches to such work. The main interest is that we can now go on and show that inductive machines can be constructed, so that general principles can be inferred as a result of conditional probabilities from a count of particular instances. This can be achieved in a variety of different ways, and we can realise in our machine any probability function whatever. This has naturally led to the realisation of certain statistical activities such as those represented by Markoff processes. This is the situation, already mentioned, where one event is followed by another with a certain probability. We can construct a computer which will operate on such a control principle, where the probabilities can be shown to change as the result of the counting operation of the machine.

The power and effectiveness of this sort of model-construction process lies partly in the fact that we can define precisely each step in the construction of the machine by a mathematical logical formula. This means that there is a relation between our diagrams or drawings — real or conceptual — and a certain part of mathematical logic, and we know that for that part of mathematical logic there is an effective

process (sometimes called a *decision procedure*) which lets us know that anything that can be constructed within the confines of the logic can be constructed, in fact, however many elements are involved and however complex the ultimate relations. We should notice carefully that this means that we can draw up a blueprint, and suggest a method by which a paper machine may be constructed without giving an element-by-element description, but by the use of a general formula we can describe a machine that we know can be translated, if necessary, into a hardware machine.

We have at Bristol built two of what we hope will be a series of computers to realise some of the principles which are implicit in the paper machine designs. These computers are themselves only stepping stones towards bigger and more interesting computers that will illustrate the inductive control which we have already been able to demonstrate in the theory. This sort of work parallels that of programming existing digital computers to learn, and these two techniques taken together must be seen as part of the effort to find appropriate control systems to control effectively any process whatever. Precisely the same features of motivation and storage have to be built into special purpose computers (both theoretical and hardware) as into the programmed general purpose computer.

We should also mention, that our work in this field is by no means isolated; there are various efforts being made along the same lines, and the names of Drs. Grey Walter, Ross Ashby, A. M. Uttley, D. M. Mackay, Colin Cherry and many others besides, spring to mind as having made such models — or special purpose computers — and broadly speaking their motive has been the same as that stated here.

Implications of these new ideas

It was said recently by an American industrialist that nothing was so certain to bring economic disaster to a firm as a good scientific idea in the hands of a rival organisation. This same state of affairs is true of countries as much as it is of firms. At the moment, the scientific ideas underlying cybernetics and operational research represent some of the most powerful of all ideas for production.

The methods of computation we have referred to are as important—if not more so from the engineering point of view—in the control of mechanical operations as in the role of a standard computer, but our next set of problems places a different emphasis on the whole matter.

In the immediate past the bulk of the efforts on automatic control systems (collectively called automation) has been located in engineering proper, and has depended on servosystems and other fairly simple closed-loop systems. This is all to the good, and latterly it has been increasingly recognised that computers could automate the office, with automatic filing systems, accountancy machines, and so on. But still insufficient emphasis has been placed on the broader organisational aspects of automation. This is the field where operational research and cybernetics meet.

We have already said that operational research is concerned with applying scientific method to any problem that does not come within the scope of the established techniques of science — a problem that is not reducible to a known type of problem in physics or chemistry, for instance.

The methods are the methods of systematic common sense, aided by the concept of science as a methodology wherein we may separate the predictive theory from the model which underlies the theory. This construction of a model, therefore, while certainly an analogue process, is the basis of the subsequent predictive theory which can be derived and from which we can deductively order our problems, however large. The models which are used here will not necessarily be physical — in hardware — but in symbols, they will be logical models, and in particular, they will frequently be mathematical, often mathematical-statistical. A set of such model construction methods has been elaborated by the writer for use in almost any situation. This set of models was called the logic of empirical relations, and involved the mapping of the classical calculi of propositions, functions, relations and so on, on to the calculus of probability. This means that much that is now discussed in ordinary language is capable of more precise restatement in our model language, and thus by suitable choice of models to any degree of precision whatever. This at first sight seems to make problems intensely complicated and, indeed, in many cases it may. The important thing is that if we have complete precision of language the complication will no longer matter, since all our models can be put in a form where they can be handled by a digital computer.

Let us now consider some of the applications this entails. We shall be hearing later of certain applications from Mr. Harling, employing techniques not substantially different from these we are describing, and within the scope of operational research. However, we may mention some problems where our techniques might be expected to yield dividends, first of all, in the organisation of any department of a large firm and, secondly, in the fitting together of the departments of these large firms, to make for overall organisation.

It is well-known from existing work study experiments that a great deal of time is lost in operations of a sequential kind that contribute towards a total production line. This problem is partly a matter of communication theory, and the application of the mathematical theory of communication in such a context is strictly a piece of operational research. This has actually been done in certain organisations, where efforts have been made to trace all the connections in the information network, to see whether or not the information is adequate, suitably coded and properly timed. The lack of these facilities has been shown to be a common cause of organisational inefficiency.

Apart from information flow we might model all the neural-muscular responses made by all the human operators, or the operations of machines that are linearly connected in a production outline. We have

clearly to maximise the time flow, which might be slowed — as the ships in a convoy — by the slowest operation.

But apart altogether from the problems of organisation for the maximum physical efficiency through effort, there are problems of a more obviously technical kind like those of production scheduling programmes, linear programming for economic problems, and so on. There is some hope that these are matters that might be handled by the construction of a suitable model and the use of a suitable computer programme.

I would like now to turn to the third and perhaps most promising of all the possible developments, also I think within the domain of operational research, but also involving the use of computing machinery.

We know that what we commonly call " goodwill " is more important than quite large differences in physical conditions that might pertain at any particular time. Industrial psychology, and particularly experiments such as the Hawthorne experiment in America, has shown the importance of factors of human relations, and we must remind ourselves quickly of these essential facts. There is a certain range of physical variables that will directly affect any human organisation, such as a factory. For example, the lighting, the hours of work, the salary, the various conveniences and social facilities, the holidays, all certainly make a difference to whether one accepts a job in a particular firm at a particular place. But overriding all these considerations to a surprising extent are the psychological variables. Let us quote a commonplace example.

Recently there has been a great deal of argument about psychotherapies. Is it a fact that psychoanalysis improves the state of those who are exposed to it ? Indeed, are any psychotherapies effective in " curing " those people who we may all agree are sick — " mentally sick " ? The answer is to try an experiment, and find a large group of people who have certain complaints, and divide them up in such a way that we have little groups that all show the same symptoms to about the same degree. Now use the various therapies on all but one group and leave that one entirely alone. Now compare results after some period of time. This experiment has been tried under somewhat limited circumstances, but the result seems to suggest that you will have at least as a good chance of recovery if nothing is done to you, as if you receive some form of therapeutic treatment.

There is an obvious " twist " to the facts stated above. It is not possible to find the patients with approximately equivalent symptoms without carrying out a fairly careful analysis of all the people concerned, and it seems as if the mere fact of carrying out such an analysis improves many such cases.

The Hawthorne experiment seemed to demonstrate exactly the same fact, that it is not — within certain limits — what you actually do, but it is the manner in which you do it that matters most to most people. It seems that affection and an interest being taken is enough to give almost every one of us a considerable fillip, and make us exhibit the spirit of social co-operation necessary to any enterprise.

This all seems easy enough, since it should not be impossible, once an employer has learned these facts, to apply them by ensuring an interest is taken in his employees; he may ensure that the contact between the different levels of his hierarchy of organisation is good, that the employer-employee relationship is everywhere personal. But this is not easy, due to the historical background of suspicion between employer and employee, because of the economic pressure that may leave very little scope for freedom of thought and action within the firm. However, this is certainly a matter that can be helped by operational research and cybernetics.

If a firm gets too large and unwieldy, it tends to become impersonal. If we can find appropriate indices of impersonality, then we can ensure — subject to the engineering and transport requirement — that the firm is split up into smaller units and a suitable *personal* size is retained. But this example is only one of a host of examples that can be treated scientifically, where we mean the word "scientifically" in its very broadest sense to include all the psychological variables as well as the historical background in which a problem should always be viewed; this is a characteristic of operational research.

The process of operational research we have already described as involving the construction of models, and these final social and industrial models involve in the limit nothing less than whole collections of individuals from various backgrounds working together as a unit.

We need to build a social-industrial model, which will suggest principles of selection and organisation for any firm. The size of the ultimate plan and the amount of detail needed is awe-inspiring and looks wholly incapable of being handled, and the answer to this is that under ordinary circumstances it would indeed be quite impossible to handle, but it is possible as long as we have the use of a digital computer.

The problems of learning machines and learning programmes, the problems of linear programming, the problems of the scheduling of organisation at every level of the largest firms, are all particular cases of the more general problems that involve nothing less than the *total organisation* of any community or group.

To make this possible we have to designate individuals by more than just a single-dimensional variable. We must decide — and this demands a study of our learning programmes — exactly what is the minimum set of variables that will designate any set of humans, and will allow for the predictable interaction in specified conditions. This way we can arrive at social indices, within which we can try and maximise the happiness, as well as the output, of the group as a whole. A study of such a system should also reveal the sort of person who should be selected for employment, those most suited to promotion, and so on. Not that it is intended to replace direct human observations and human considerations, but rather to facilitate them.

Ultimately the number of human operators will be replaced by machines, and again we might expect our programming to facilitate the changeover from humans to machines, by studying the human in a variety of different and characteristic situations. When the change is largely effected, this still leaves our social computer programmes as applying directly to the machine control systems themselves, since our cybernetic theory makes no essential distinction between machines and organisms.

Programmes have already been constructed which aim to model social situations, stochastic models have been used to characterise the human being in social situations and these models could be used as the basis for a computer programme. Theories of learning, which are essentially the same, and theory of games can be also put in a computer programme form.

From these more general programmes, can be extracted models which will mirror virtually any sort of organisational situation with, of course, the practical problem of eliminating wastage due to bad selection, and bad internal organisation, both in ordinary physical terms and also in psychological terms.

Perhaps it should be stated explicitly at this point that the benefit of these operational research techniques are more in the attitudes they engender and the concepts they produce than in their immediate and particular application. Queueing Theory, set theory, recursive function theory, and all the other possible fields for models that we have previously referred to, are abstract models that can be used to represent different physical events by analogue techniques. But this use of models is only effective in the general background of rigorous scientific application.

At the machine level, we shall expect the application of general theories, such as those which logical nets should produce as particular cases, the methods by which we may construct self-maintaining machines and self-servicing machines, and machines for quality control. In general we might expect to model anything whatever, even to the extent that market research activities, and other sales activities and research, could be modelled and thus carried on wholly by machine.

These are all general statements which can be proved at the theory level, but mostly need to be demonstrated at the practical level. Needless to say their application to particular problems may involve considerable practical difficulties, not the least of which will be that they are uneconomic to apply, or may be at any given time.

Practical approaches

If we are to make use of the very powerful weapons with which science is able to supply us, we must have practical experience of the situations to which they are applied, as well as the scientific knowledge to apply.

The biggest barrier to this application in the U.K. has certainly been in the relatively backward role of the technical college, and the inadequacies of our educational system, especially in technical education, where there is a tendency to teach particularities rather than to give the general scientific training which is essential if we are to be able to make applications. This implies the urgent need to reconsider our educational system, and for industries to take very seriously the educational services they offer. Generality should be much more the aim in the future than it has been in the past.

Apart from the various problems that the educational process throws up, there are the practical applications of all we have said. How do we set about applying such knowledge ? The answers are so various that to generalise is now difficult, but we can say that the first step, granted the necessary knowledge of science, is to investigate any firm's organisation from the broadest possible point of view, with the idea of constructing detailed flow charts for all the processes carried on, with a clear picture of where all the external inputs and outputs come from (and go to) and what this entails both economically and in engineering or other organisational terms. It is not reasonable to analyse and automate — in the widest sense we have been implying — any part of a system without a fairly good knowledge of that larger system, of which it is a part.

From this picture we can abstract that part which lends itself most readily to replacement of human operators by automatic control systems, and this depends on what our control systems are capable of at any given time. Then this may also mean, taking automation again in its widest sense, the consideration of communication and other organisational problems within the department, or the firm, irrespective of whether or not automatic controls are to replace human operators.

The larger picture is vital to this process, because there is little point in greatly improving the organisation of a section that is already one of the faster sections in a production line.

Also we have to consider the effect on the rest of the firm if some part of it is made automatic, and not the least of these considerations is the effect on the human beings who are involved, whether or not they are displaced.

This also suggests that we should always consider two vital factors; what changes are likely to occur in the foreseeable future so that we can show the maximum amount of flexibility in planning, taking only a certain minimum of things as fixed and making everything else easily changeable. And this leads to the second point : is it not possible to rethink a part or the whole of some production operation ? And if this is not possible all at once, then in what order should it be done ? Failure to rethink sufficiently to allow careful planning can seriously hamper an application of automation. Where smaller and newer firms are concerned, the planning-as-a-whole will automatically be a vital factor, but even here it must be elastic and facilitate change.

In particular the first step for any department is to document carefully exactly what is performed, specifying the order of the operations in great detail.

This should lead to a detailed flow chart, which is something that could be coded into a computer programme. Then the programme, which may, in the limit, include human factors — where they are involved — will be examined with the simple idea of making it optimal, with respect to certain characteristics, of efficiency time, etc.

These detailed analyses of operations actually performed have already been used to reveal methods of an improved character that increase production. Here though we are thinking of them as stepping stones to setting up careful programmes which will automatically compute wastage points and other weaknesses in the production situation.

Finally, we might feel obliged to answer a possible criticism — and it is a very real one — to the effect that what has been said here offers really nothing new. Is it not already a fact that industrial psychologists have long worked on time-and-motion studies, economists and statisticians on linear programmes, and organisers tried to improve the facilities in any factory, and this most recently has been mainly in the consideration of automatic control replacing human operator control ? The answer to this is that while all these things have been done they have never represented an integrated effort to solve the problems of the factory or the production line all at once. It is not perhaps surprising that attempts to understand human behaviour, the human nervous system and the other systems of the body have increasingly emphasised the need for seeing the problem as a whole, and it is this method that seems essential to follow up in the future.

Granted that we must analyse and then resynthesise every aspect of an industry, and continually do this, and provided we use logical and scientific methods in the way I have been describing, will it not be the case that the problems will be far too big for us to handle ? After all, attempts to solve the production scheduling for batches, for example, is seen to be exceedingly complicated, and not one that a logical programme could readily handle, and yet this is only a small part of the bigger picture. The answer to this is that we are certainly suggesting the systematic and wholesale use of scientific models, we are certainly suggesting the possibilities of new programming techniques in the application of computers, where digital computers are increasingly being used as simulators of various complex systems. The trick is to partition our problems from our large scale scheme of things in such a manner that although all the individual problems are stated in a separate handleable form, they are nevertheless structurally related to all the other problems that lend themselves to a computer programme. This means that we shall not be considering one set of computer results independently of other computer results; this really implies the use of a common language and, therefore, a common model, for all our organisational problems, and one aspect of this is the use of automatic machinery to do jobs previously done by human beings.

To supply these models is the next step, and here we have mentioned the various models that have so far been worked on, often with quite different underlying motives. Logical nets, stochastic and other statistical models, and computer programmes, both deductive and inductive, might be mentioned here; what unifies them all is the theory-model approach to scientific method and it is the application of this, as much in *changing our attitude towards problems of production*, as anything else, that represents the big possibility inherent in cybernetics and operational research.

" SELLING IN WORLD MARKETS " — concluded from page 609

The **Chairman** pointed out that a lot of people were scared of the problems of exchange and so on. They had been so busy dealing with their home market that they had not been prepared to face difficulties, some of which were only in their own imagination.

The **President** (*Lord Halsbury*) said that for a small country which might be exporting only a small proportion of its product, the total number of people required to make a success of it was relatively small. The U.K. exported 20% of its manufactures on an average, and up to 40% in some classes. Were 20% - 40% of our best people assigned to the job ? If not, was it because they couldn't be spared ? He did not know the answer to such questions.

Dr. Hague said in some ways there could be quite a difference between sending British equipment to, say, British Borneo and Venezuela. A background of usage of British materials — maybe with little or no American competition — was on easier export ground than where the Americans had the " inside track ". In Venezuela, for example, British and American oil companies were working alongside one another — comparisons were naturally keen.

Mr. Hughes said he was very much struck with the rate of increase in exports to the United States in recent years. It had gone up by leaps and bounds. This might justly be attributed in some measure, he thought, to the fact that for 10 years now there had been a special effort to send exports to the dollar countries, particularly the United States. People had really taken a lot of trouble to develop their exports to that market.

Dr. Hague asked Mr. Hughes if he could say what percentage of this upswing in U.K. exports could be attributed to the automotive industry — he thought it must be quite large. He went on to say he had been pleasantly surprised at the success British cars had had in recent years in the U.S.A.

Mr. Hughes said he did not remember the exact figures but cars had certainly come up enormously in the last year or two.

The **Chairman** said he was surprised more people did not go to the dollar countries referred to by Sir John Taylor, the countries of Latin America. They were so much easier to get into than the United States and they were not only extremely friendly, but very profitable. It was unfortunate that they had been neglected.

The Chairman, in bringing the meeting to a close, expressed the view that the Forum had been very satisfactory. Clearly there was great interest in the subject and the questions had been of an extremely high quality.

He thanked the members of the Forum and expressed the hope that they would not feel their time had been wasted. What they had said would be read by many members of the Institution and other people in due course and would, therefore, reach a very wide audience.

The **President** (*Lord Halsbury*) thanked the Chairman on behalf of the Conference for presiding with so much grace, charm and affability over the proceedings.

Operational Research Case Studies

by John Harling

Presented at the Production Conference, Olympia, on 15th May, 1958.

1. Introduction

The main purpose of this Paper is to give a few examples of the application of operational research methods to practical industrial problems. The examples are preceded by a brief outline of the nature and scope of operational research.

Lastly, operational research is placed in the context of related fields.

2. Scope of operational research

Most definitions of operational research fall under one of the following heads :-

1. formal definitions;
2. historic definitions;
3. definitions by techniques used; and
4. by types of problem studied.

In the writer's view, none of these definitions is satisfactory.

Probably no formal definition of a living field of study is possible. What, for instance, is History ? Such definitions tend to be too broad to have any meaning or else too narrow to be true. Morse and Kimball [1] define Operational Research as the provision of a quantitative basis for management decisions, but if this is so then every accountant is an operational research worker. Again, operational research is defined as the application of the scientific method to business problems. While this definition recognises the difference between using science in the laboratory and using it in new fields, it is a somewhat restricted one.

At the first international conference on Operational Research held in Oxford last September, the American delegation were greatly preoccupied with defining their subject. On the other hand, the British delegation preferred to describe what they had done.

The term "Operational Research" was coined in this country during the War. A good account of the wartime work is given by Blackett [2]. However, it is doubtful whether any clear impression can be gained from a historical survey of Operational Research, although Trefethen [3] gives a useful summary of post-war developments, and Goodeve [4] gives perhaps the best connected account of British work in the field. The trouble with historical definitions is that they cannot avoid losing themselves in a mass of detail.

Many attempts have been made to define Operational Research in terms of the tools it uses. This is surely the worst way of all, because it confuses means with ends. Thus Operational Research becomes identified with Linear Programming, with the Theory of Games, or with the study of Waiting Lines. As in any practical subject, the problems faced by Operational Research should be allowed to create the techniques, and not the other way round. Otherwise, the operational research worker will tend to force his problem into the mould of what he already knows and, therefore, to ignore the factors which dominate the problem he has to solve.

Gunther [5] gives an amusing illustration of the results of this 'cookbook' view of Operational Research; not only is such a view disastrous in practice, but it is quite foreign to the ways of science.

An account of problems studied is perhaps open to fewer objections than any of the above. These problems can to some extent be classified (see Section 3), and provided that the list is not regarded as being exhaustive, then it does give a rough working definition of the subject.

However, such a list is really no more than an inventory of work currently being done, and cannot help to define the boundaries of Operational Research.

My own opinion is that Operational Research is really a point of view. When people trained as mathematicians or scientists come face to face with the operating problems of a business, then Operational Research is what happens. The techniques are necessary, and the scientific method is necessary ; but what seems to characterise Operational Research is the coming together of the man with his background and the problem.

Section 3 outlines how this has worked out in practice.

3. Types of problem currently studied

Problems currently studied fall under the following heads :-

1. control of stocks and production scheduling;
2. programming and allocation problems;
3. waiting line and congestion problems;
4. miscellaneous problems, e.g. tender bidding, determination of price structures.

We emphasise that any listing of problems cannot hope to be exhaustive. The field of Operational Research is expanding rapidly. Therefore, any such list is no more than a statement of achievement up to the present.

control of stocks and production scheduling

When a company holds stocks — whether of raw materials, in-process parts, or finished goods — it has already decided to invest working capital in giving service to its customers. If the company holds no stocks, then its customers will have to wait for the goods they need. On the other hand, the company can obviously over-invest in stocks; it can provide a level of service to its customers which is prohibitively costly. Between these two extremes there lies a best level of stock-holding, and the main purpose of an operational research study of stocks is to determine what this level is.

The manufacturing company must also decide the most economic way to make its products : should the company have long runs on a single product, or should it try to make many different products in a single day ?

These questions have been widely studied by operational research workers. Two examples in this field follow.

A company packing goods for consumer re-sale maintained a large warehouse containing a wide variety of packaging materials. These included many kinds of cardboard carton, many hundred different labels, and an assortment of bottles, caps and containers, amounting in all to some 3,000 items. All these items were bought by the company from outside manufacturers. Most items were used every week, the amount used depending upon the production schedule for the week.

There were two sources of uncertainty : first, delivery times from outside suppliers were uncertain. An item might take 10 weeks to arrive or it might arrive in five weeks, or perhaps in 15. Second, the amount of the item used each week by production was also uncertain. The problem was this : how much stock of each item ought to be held in the warehouse to keep the chances of running out of stock down to whatever level the Board of Directors might prescribe ?

Examination of past delivery times into the warehouse showed that these times followed the normal distribution. Appropriations from the warehouse were made every week in terms of some number of standard factory lots. These appropriations were found to follow the Poisson distribution.

If the lead-time t has a frequency function $f(t)$, and the conditional probability of a withdrawal of more than u_i units in time t is $p(u>u_i|t)$, then :

$$p(u>u_i) = \int_0^\infty p(u>u_i|t)\, f(t)\, dt$$

is the unconditional probability of a withdrawal greater than u_i during the lead-time. Knowing the two distributions on the right-hand side of the equation, $p(u>u_i)$ can be calculated and so a protective stock level set which will secure that the probability of running out of stock (during the delivery time) is kept down to any chosen level.

Mr. Harling is a scholar of Balliol College, Oxford, where he read mathematics and physics and took First in the Honours Schools. Far East active service in the Royal Signals gave him a thorough appreciation of the practical application of science to the problems of everyday life. He followed this with research appointments as a physicist in work on crystals and other specialist applications in communications, both in the U.K. and the U.S.A.

His particular bent for research and applications of mathematics and scientific method led to an appointment in the recently-formed Operations Research Group of the well-known Arthur D. Little Company, of Cambridge, Mass., and his wide experience in Operational Research methods is largely derived from having worked as a consultant both in U.S.A. and U.K.

Mr. Harling is now with ORbit (Operational Research) Ltd., where he is Senior Analyst.

A simple computing routine was developed for evaluating this probability in such a way that whatever level of protection was chosen by the Board could be translated into definite amounts of stock for each item. The company had previously maintained a "blanket" policy of a fixed number of weeks' sales as protective stock. This amount was clearly too much in the case of "bread-and-butter" items, and far too little for items whose weekly appropriations were uncertain. A study of the actual distributions, therefore, secured that protective stocks were correctly allotted across the whole range.

Lastly, the results of the study were explained to the Board, and the computing routine reduced to a simple computation sheet for use by the company's clerks. This last stage of translating the results of an operational research study into practical terms is of crucial importance. Not only must the work be explained "upwards" to the Board, but also "downwards" to the people who will have to put it into routine use.

The next example is of a combined production scheduling and stock control study.

This study was undertaken for a medium-sized company in the light engineering industry. A wide range of products was made involving the use of high cost capital equipment. The company's practice was to run their factory as a job shop. That is, no finished stocks of goods were carried and production was geared directly to customer demand.

Long down-times were incurred in many of the heavy machines when changing from one product to another. These setting times could amount in some cases to the loss of a whole day's production.

The purpose of the study was to design production scheduling and stock holding methods to secure the following :-

(a) the Board's policy on service to customers would be carried out;
(b) production to be scheduled in accordance with this policy;
(c) consistent with the above, production to be scheduled at minimum cost.

The main costs involved in the study were those of carrying finished stock on the one hand and lost production time due to machine change-overs on the other. Some difficulty was found in measuring these costs, but a range of possible costs was obtained from the cost accounting department.

In reaching the objectives defined in (a), (b) and (c) above, the following stages took place :-

(i) sequencing the products to incur least change-over cost;
(ii) finding optimum batch frequencies;
(iii) finding optimum batch sizes;
(iv) designing of control rule to secure that stocks did not wander from the chosen levels.

Consider four products, A, B, C and D. Associated with every transition or change-over within this group there is a downtime cost. For example, the transition A→B might entail four hours' downtime; the transition B→C, two hours; C→D, six hours; and D→A, eight hours. The problem here is to find the permutation of the products which secures that the transition costs are at a minimum.

This is a theoretical problem of some interest and has not been solved in the general case. However, in this study the form of the matrix of transition costs was such that a "least cost path" could be found through it by inspection.

batch sizes

Large batch sizes mean low change-over costs per unit time but high stock costs. Conversely, small batches secure that low stocks are held but entail frequent change-overs. If the change-over costs and stock costs are both known, we can determine the optimum batch size. An important point is that these optimum batch sizes are not critical. Deviations from the optimum value, especially on the higher side, do not make much difference to the total costs incurred.

Optimum batch sizes were determined for the range of products manufactured by the company.

batch frequencies

As it stands, the elementary treatment of optimum lot sizes cannot be applied to the scheduling of many products in the most economic manner, owing to the importance of correct sequencing. To get over this, methods were developed for determining for each product how often a batch ought to be made. An expression was derived, depending upon the sales volume of the product, on the ratio of stock cost to change-over cost, and upon the level of customer service required. This expression was used to determine how often each product should be made. For example, for certain values of the cost ratio and the sales volume it was proved most economic to make the product every week : in other cases, every two weeks, in some cases, every four weeks, and so on. Optimum sequencing, as just described, can then be worked out, and the batch size for each product calculated.

control rule

In addition to specifying correct stock levels, we must also ensure that deviation of actual sales from forecast does not cause stock levels to wander away from the chosen values. A feed-back control rule was, therefore, designed so that stock level errors could be fed back into production to keep the system stable.

presentation to the company

The final presentation consisted of a simple account for the Board of what had been done, plus a detailed operating manual for the company's continuing use.

benefits of study

These may be summarised as follows :-

(a) a direct saving in production time of £40,000;

(b) a true control system — that is, not only could the company's service policy now be accurately carried out, but provision was made to ensure that this continued to be so.

programming and allocation problems

The second important class of problems which have been widely studied by operational research methods is that involving the allocation of resources. Typical of these would be the following: given a company with several factories making many different products, how much of which product should be made in which factory? Related to this are linear programming problems.

Although linear programming has received wide publicity both in this country and in the United States — and in the minds of some, is identified with operational research as a whole — the method is of restricted application. A brief example of a linear programming problem follows.

A company manufacturing animal food mixes required to know the least cost composition of a set of mixes which would satisfy the dietary requirements laid down. These requirements are of the form "not less than x per cent. albumen", "not more than y per cent. of some other ingredient", and so on. Various components are available, each containing a known percentage of one or more of the dietary requirements. The object of the programme is to find the least cost mix.

This is a straightforward linear programming problem. There were enough components and dietary requirements to justify solving this problem on an electronic computer. The machine found the least cost solution in about six minutes, whereas hand computation would have taken about two weeks. Trial and error methods previously used by the company had failed to find the least cost mix and a saving of around 5% was obtained by the linear programming solution. Since the company made a large volume of the food every year, this saving amounted to a considerable sum.

Classical linear programming methods are of restricted application, not so much because of the linearity requirement, as because they do not take account of inter-action between ingredients.

waiting line and congestion problems

These problems have been studied for many years by mathematical statisticians. Early work was centred on finding the capacity of telephone exchanges so as to keep peak hour waiting time down to whatever value was desired. Subsequently, this work was extended to a variety of congestion problems.

Any waiting line problem has the following ingredients :-

(a) a distribution of arrivals;

(b) a distribution of service times;

(c) a queue discipline (e.g. "first come, first served");

(d) a number of service points.

Provided that the forms of (a) and (b) are known, that (c) is fairly simple, and that (d) is specified, the problem can be solved theoretically. Examples of such solutions are given by D. G. Kendall [6], R. R. P. Jackson [7] and others. Solutions are available under a wide range of assumptions as to the arrival and service time distributions. However, deviations from the simplest queue disciplines cause serious analytical difficulties, and in these cases, a simulation method is to be preferred. The use of simulation is best explained by means of an example.

The purpose of this simulation was to discover the most economic level of pier wharfage facilities to provide for barges bringing grain and removing finished milled products from the same group of wharves. Clearly, if insufficient wharfage is provided, then barges will have to wait and incur demurrage. On the other hand, if an over-investment in wharfage capacity is made, then there will be long periods during which the piers are idle. Any calculation based simply upon the mean arrival rate of barges will inevitably fail to take account of the bunching which takes place in the arrivals. This bunching will lead to periods of time during which barges must wait for a wharf, and also periods during which wharves are waiting for barges. Both of these eventualities cost money, and it was therefore required to determine what the most economic level of investment in wharfage facilities might be. This level cannot be calculated from a knowledge of the average arrival rate alone.

In addition, due to restricted loading and unloading facilities, not every type of cargo could be handled at every wharf.

This problem is clearly of the waiting line type, and required the following distributions for its solution :-

1. distribution of arrivals per unit time;
2. distribution of alongside time.

It is required to find the response of the system in total waiting hours per year, when the system is subjected to a plausible range of future arrival densities of barges. The control variable is the number of wharves.

A year's data on arrival times and alongside times were examined, and although some scheduling of the barges was attempted, the arrival distribution was found, according to the χ^2 test, to be Poisson, and the alongside time to be almost normal. A first model was set up which ignored the berthing constraints with the purpose of testing *in situ* whether the actual arrival and service time distributions generated the same number of waiting hours per year as the theoretical distributions to which they belonged.

A small experiment was designed as shown in the table below:

Experiment	*Arrival*	*Service Time*
1	T	A
2	T	T
3	A	T
4	A	A

where A denotes the actual arrival or service time distribution and T the corresponding theoretical one.

Each experiment was run and replicated five times. No significant difference was observed between experiments 3 and 4, nor between experiments 1 and 2. From this, it was concluded that the normal distribution was an adequate representation of the facts. On the other hand, there was a 1.5 to 1 discrepancy in waiting time between experiment 2 and experiment 3, and also between experiments 1 and 4. This indicated that although the arrival distribution appeared to be indistinguishable from the Poisson one in terms of the χ^2 test, it nonetheless failed in the context of the problem to represent the true state of affairs. This last discrepancy underlines the need for a careful examination of the components of the model before putting it together on the machine.

The waiting time generated by the theoretical arrival distribution in experiment 1 was consistently larger than that of experiment 4. The inference to be drawn from this was that some vestige of the scheduling process from the docks up and down stream remained in the pattern of arrivals, which were in some sense " less than random ".

It was therefore decided to apply controls to the Poisson arrival distribution, in order to generate the same amount of waiting time in experiment 2 as had been produced by the actual arrival distribution in experiment 3. The details of this control mechanism need not concern us any further here, but it was so arranged that the experiment 2 waiting time lined up with that of experiment 3 over the necessary range of arrival densities.

A forecast of future arrival densities was obtained from the company and the barge operators, and the completed model, with berthing constraints built into it, was run for various arrival densities and various numbers of wharves.

By this means, it was possible to relate the cost of investment in wharves to the expected total waiting time of the barges at various arrival densities. Provided that the unit cost of waiting and the unit cost of a new wharf are both known, then the most economical level of investment in wharfage at any given level of arrival density can be calculated.

In addition to experiments of the Table, an investigation was made of the effect on total annual waiting time of the standard deviation of the service time distribution, keeping the same arrival distribution. Although, as expected, the total waiting time depended sensitively upon the mean of the service time distribution, it was quite insensitive to changes in the standard deviation over a 2 to 1 range. This result was somewhat surprising, since one feels intuitively that the occurrence of a small number of very long service times should affect the total waiting time considerably. The traffic intensity of the system was close to unity, and so this result becomes even more surprising.

It is felt that small deviations from true randomness in the arrival distribution may be fairly common in industrial problems, because there is usually some scheduling of arrivals attempted. This is a question which should be of some interest to theoreticians.

4. Relation of operational research to other fields

We noted in Section 2 that operational research was characterised by a point of view, rather than by its techniques or the problems studied. The point of view is that of the scientist called upon to use the habits of thought of his discipline in new contexts. However, the mere use of scientific methods, even in new fields, would not be enough to distinguish the operational research worker from, say, the business statistician.

The really distinguishing feature of the operational research worker in industry is his view that the operations of a business as a whole are a valid subject for scientific study. The tools of this study are seldom original; in the examples of Section 3 frequent use was made of the methods of mathematical statistics, and of various ideas taken from several branches of science. Nor are the problems themselves very new; the need for correct investment of working capital is as old as business. But to treat a company's stock investment as a natural phenomenon needing exact investigation is new.

The view that business operations can be studied like physical systems in the exact sciences means first of all that theories, or abstract models of the operations can be constructed. A model in this sense is a simplified abstraction of a real system to which formal mathematical properties can be attached. Just as the Bohr atom was an abstract model of the real hydrogen atom, so models of stock or of a production process can be constructed and their properties worked out. And as the Bohr model was used to predict the Rydberg constant, so the models of operational research are used to predict the response of real business operations to prescribed conditions.

However, the purpose of this Paper is not to stress the differences between operational research and related disciplines. The subject has points of contact and areas of overlap with several other fields — especially where techniques and methods are concerned. Some of these relationships will now be described.

cost accounting

Costs are needed in nearly all operational research studies. In finding best stock levels, the costs of carrying stock must be known; in production scheduling, the cost of production change-overs must be specified. The task of measuring these costs does not really fall upon the operational research worker. Cost accounting has been concerned for a long time with measuring variable costs, and with means for controlling them. The cost accountant and the operational research worker should therefore work closely together.

One might say that the cost accountant designs the measuring instruments upon whose readings the operational research study largely depends.

work study

Let us not argue over definitions. In this Paper, work study is taken in its narrow meaning of

measuring work. We must note, however, that in some people's view, work study and operational research are the same.

As with costs, the results of work study are often invaluable to operational research. For example, a work study of the learning process may be needed to find the cost of increasing production by hiring new operators. In some ways, work study is an input datum to cost accounting just as cost accounting is to operational research.

econometrics

This is a theoretical subject in its own right. It differs from operational research insofar as it is occupied with the economy as a whole, whereas industrial operational research studies the individual firm.

computer programming

The simulation of Section 3 showed how some operational research studies may involve the use of electronic computers. Should the operational research worker himself know how to program one or more machines ? The question is not easy to decide. As long as programming remains an art or a skill, and a skill acquired on a single machine, programming is probably best left to professional programmers who know their own machines well. The advent of program assembly routines is beginning to take the force out of this argument. As a general rule, a man should program his own problem if he can do so without doing it badly, and without losing sight of his problem amidst the idiosyncrasies of the machine. Assembly routines help him to do this; up to a point, he can assemble his program in blocks and leave the rest to the machine.

The plain fact is that many programmers have no idea of the nature of operational research problems, and tend to see them as occasions for showing what their machines can do, rather than as problems calling for solution. On the other hand, an operational research worker is often handicapped — especially in simulation problems — by his ignorance of short ways of doing difficult operations on the machine.

Here, again, is an example of the need for collaboration between the operational research worker and a man in another field.

To sum up, we have in this country several different sets of people who are working in related areas. In general, these sets are disjoint : no member of any set is a member of any other set. Thus theoretical statisticians are developing tools for solving waiting line problems without perhaps knowing what the practical problems are, nor how computers can help with them. Many programmers know nothing of mathematical statistics, and have little contact with practical problems. Business itself, concerned with practical problems, knows very little about either the uses of theoretical statistics or the capabilities of computers.

Conclusions

We have treated operational research in this Paper under these main heads :

1. types of problem studied;
2. methods used;
3. as a point of view.

Many problems studied by operational research workers are identical with those of the business statistician. Whenever statistical methods are applied to the operating problems of business it surely does not matter whether we call it operational research, business statistics or anything else.

However, there are some problems in which statistical methods are applied not to operations but to an analysis of the past : for instance, in market research surveys. Conversely, not every operational research problem involves the use of statistics : linear programming is a deterministic technique.

By definition, the tools of the business statistician are those of statistics. Of these tools the operational research worker makes extensive use, although in practice he is more often called upon to use the simple ones rather than the refined ones. For instance, the stock control and production scheduling studies described in Section 3 used nothing more sophisticated than the elementary properties of normal and Poisson distributions.

I do not want to raise in this Paper the question of how probability theory is related to statistics. The operational research worker is concerned with both. However, he relies more often on results from probability theory, perhaps because he is more interested in crude guesses about the future than in precise inferences from the past.

Nearly all processes in business involve uncertainty : deliveries of raw materials into the company, the day-to-day behaviour of production, the volume of sales per unit time. Wherever uncertainty occurs, the methods of statistics and probability theory can be applied. Thus the methods of operational research and business statistics are mostly the same.

A definition of operational research which I have kept to the end of the Paper is the following : operational research is research into operations. This involves the research process as the means, and the operations of business as the subject of study.

The research process as such is not committed to giving an answer to a question in a finite time. No one knows what is going to happen next in research. How then can the operational research worker be said to use the processes of research, since he is required to provide an answer to his problem before it is too late ? I think the answer to this question is to be found in the historical origins of operational research. The question put to the early workers was not : " what is the best way to do this ? ", but rather : " can you find a better way quickly ? Give us that, and then we may be able to give you more time to find a better way still — perhaps even the best one ".

FOR REFERENCES SEE PAGE 652

DISCUSSION

Chairman :

H. Wilmot, C.B.E.,

Chairman of The British Institute of Management

OPENING the discussion **Mr. Blackwell** said he understood from the example given by Mr. Harling that the average figure was 15 and the standard deviation 5. Did the standard deviation apply to all commodities or was it just a rough average ? If it was an average, was it not important to note whether some commodities of factory equipment deviated considerably in the warehouse from the overall average ?

Mr. Harling replied that the figure was computed separately in each case. In answer to a further question, as to whether the figures obtained were consistent with the average $\pm$ the standard deviation, Mr. Harling said that they were not. The average was not taken: each distribution was computed separately.

Mr. Blackwell said it was stated in the Experimental Education Journal that if children were taught logic directly, a very considerable improvement could be obtained in their reasoning powers. There was a 40.5 standard deviation after three months' logical training. Since Dr. George had said so much about induction and deduction, would he back up that finding ?

Dr. George said he had always had the impression that it was true, but he could not quote any instances to confirm it. In other countries where abstract algebra was taught to children of 6, 7, 8 or 9, they had shown themselves extraordinarily efficient at manipulating abstract ideas. This he would take to be confirming evidence, but a great deal more experiment would be necessary. The difficulty was largely connected with the particular children on whom the experiments were made, and the public feeling against experiments of this kind, especially on the part of the parents concerned.

Mr. Blackwell said the children who were being taught logic were elementary, not secondary, children.

Dr. George said he would have thought there was a great deal to suggest that this was a good tendency. Perhaps more important overall was that the mistake had been made of teaching particularities too much rather than generalities, in all education and especially in this country.

Mr. Jones said that the stock model covering the running out of stocks at a particular time was a fairly straightforward exercise. The difficulty was to assess how much it would cost to run out of stock and not to be able to supply within a given period; in other words, how to assess the cost of being able to supply this afternoon or tomorrow morning.

Mr. Harling said that in general companies were reluctant to specify what was the cost of running out of stock. It was for that reason that it was taken in terms of the level of protection.

What one could do was to say that the present policy corresponded with some particular valuation of the cost of running out of stock. This was a subjective matter and at any rate at the moment one did not know how to quantify it. This was why that particular approach had been followed.

Mr. Jagger asked whether he had correctly understood Mr. Harling to say that the problems which could be treated under operational research were restricted to the four or five general types he had described.

Mr. Harling replied that he had said exactly the opposite.

Mr. Murray, referring to stock input frequency, asked how far back it was necessary to go to obtain a reasonable figure for distribution. Going a long way back, had the company's stock policy changed over that period ?

Mr. Harling said it was always a problem to decide how large the sample should be. If it was small, the advantage was that it was likely to be homogeneous, but purely from the statistical point of view little information could be extracted from it. If, on the other hand, it was large, it was useful from the point of view of mathematical statistics, but it might well be non-homogeneous. It might relate to a time in the past which did not reflect present conditions. One had usually to examine the data and take, say, some period under a year. One would probably go on increasing the sample until it failed to pass the necessary test for homogeneity. That was a possible method.

Mr. Murray asked whether there was any way of estimating the standard deviation.

Mr. Harling said that there was a large literature on this subject. Dr. Cox had done a lot of work in the field.

Mr. Novelsky asked Dr. George if he could give as simple an example of problems treated in cybernetics as his example of the scientific method of studying shops in Bath.

Dr. George said the question was whether one *could* give any simple example of cybernetics. He would have thought questions about cybernetics were 64 dollar questions.

One example though was to decide how the human brain worked. As Mr. Harling had said, he had made his computer behave like a human being in deciding the input of ships and the waiting time. It was necessary to decide how much information was wanted to start with and how to classify and store it. The position of the input in storage was important. How a decision was made at a particular instant was the result not only of the input received at that instant, but also of the state of the storage at the same instant, and of the fact of the storage deciding at that instant what the output should be.

Increasingly, one had tried to set up a functional picture with the idea of constructing a model that worked in much the same way as a human being in making decisions. Hence, the difference between cybernetics and operational research. Whether it used a general purpose digital computer suitably programmed or a special purpose computer, especially made, did not matter. The question was how to arrange the instructions so that the output of the machine became a function of what was in store.

One of the most interesting problems was concerned with the organisation of storage and the queer fact that there

was some sort of instruction enabling human beings to draw deductions and inductive inferences from the general information put into their storage systems, perhaps at the same time or during quiescent periods when they were not dealing directly with input information.

This led to a general attempt to construct a model in simple effective terms, operational terms, for human behaviour; in the initial stages functionally. This was the problem with which Dr. Grey Walter, Ross Ashby, Uttley and others were concerned. It was, he would say, the most important single problem in cybernetics.

Mr. Harling pointed out that *his* model was deductive rather than inductive. It was stochastic and remained deductive. No learning process was involved.

Dr. George said he had only drawn attention to the fact that Mr. Harling was turning a general purpose computer into a special purpose computer by suitable programming, and then using it as an analogue of another system.

Mr. Millington said he would like to refer to work in the field of management decision. The theories and techniques described were very fascinating, but by the very nature of the work it must be expensive. He wondered whether there was many cases where it could be justified in view of the uncertain nature of the information fed in.

Did one know, for example, just how the pattern came in ? In the question of which came first in the queue, it did not usually continue for many days or weeks, as one would like it to do. There were many things that might wreck the otherwise perfectly accurate calculations which had been made.

Mr. Harling pointed out that if there was no uncertainty in the system there was no need in 9 cases out of 10 for operational research. One used methods of mathematical statistics constantly, but if there was no uncertainty there was no need for them. Secondly, it was true that, for instance, queue disciplines and problems changed, but the computer model could be amended accordingly.

Mr. Broome said he did not belong to a technical branch but he was concerned with the constant experiments and research in the aircraft industry. New models were always being made and the cost must be very high. He would like to know how much this was costing the nation; it was his impression that a lot of money was being wasted in experiment and research in the aircraft industry.

Mr. Harling regretted that he did not know.

Mr. Jones said that no mention had been made of optimisation. He was prompted to ask, with regard to queueing, whether it would not be possible to route tankers to some other port.

Mr. Harling said that in that case the refinery would not get the crude oil it needed.

Mr. Duckworth asked Mr. Harling who, in his opinion, should be responsible for operational research ?

Mr. Harling said there were various possibilities but the problem had not been solved yet. At the Philips Company in Eindhoven, a very large company with subsidiary companies in different countries, the operational research group reported to the Board. Over and above that in the subsidiary companies there was a small " splinter " from the main group whose job was:

(a) to pass back potential operational research problems from the subsidiary company to the main company; and

(b) to ensure that any work done by the main group was carried through into effective practice in the subsidiary group.

He had a feeling that the impact of operational research on existing management structures was not really understood at the moment. It would have to be faced soon in this country.

Mr. Burdett, referring to the examples given by Mr. Harling, asked whether the investment, or possibility of reinvestment, of money tied up in the stock when the method chosen did not involve changing over production, was also taken into account.

Secondly, the management decision had reference to the making of models, but surely the circumstances could change completely and this would necessitate a completely new model. Would this not be true of many problems to be tackled by operational research and would not the model have a very limited life ?

Mr. Harling replied that everything had a limited life, especially in science. There were three things that could happen to a model after some interval of time. It could remain adequate; it could be inadequate to a point where it had to be modified; or it might have to be abolished and another created.

Fortunately, it was found in many operational research studies that the half-life of the model was usefully long.

Mr. Millington asked where his ego came in if the machine could be made to do anything the human being could do. He assumed it worked inductively and not deductively. Was Dr. George serious about this ?

Dr. George replied that he was quite serious. However, he assumed that would not be regarded as a satisfactory answer. He was sorry about Mr. Millington's ego, but the facts would appear to be fairly well founded, and one had to get used to them. The possibility of deductive systems was relevant, but he did not want to break into that question at the moment.

There seemed to be a great deal of evidence to suggest that there was no obvious operation which human beings could perform that machines could not be made to perform. The line taken was that a mathematical theory could be developed whereby a machine could evolve in the same way as a biological system. This was mainly developed, by von Neumann and others at Princeton, because people criticised the general statement that there was nothing the human being could do that the machine could not do.

Turing dealt with the same point in some of the earlier Papers. It was clear that there were some operations that could be done more competently by a machine than by a human being, and no doubt this had a similar effect on the ego. But the fact remained. No one was going to build a human being, he supposed, but the result of the theory was that there were particular applications of which Mr. Harling's was one, and only one, for there were a lot of others, which were going to affect the organisation of society.

Mr. Simons asked whether any operational research work had been done on guiding and predicting the result of research problems.

Mr. Harling said that some work had been done. It was not precisely on that subject, but attempted to relate the creativity of research scientists to the circumstances in which they found themselves. This was the only work even remotely related to the subject of which he knew.

Dr. George said that one of the objects was to produce machines which would perform the same inductive operations as human beings. It was true that in large branches of mathematics, wherever a possible decision procedure existed, the machine was more effective in utilising it than the human being. There was some reason to suppose that new branches of mathematics and science would be systematically explored, and that generalisations would be formulated by machines as efficiently as humans, if not more so.

Mr. Bledstone said with regard to the theory and problems of queues, he was associated with Mr. Henry Ashcroft's work on the number of machines per operator. His mathematical work seemed to be of more general application than the specific problems to which it was addressed, but it seemed to have disappeared from the literature. Was this because it was inadequate or because better theories had evolved since ?

Dr. George said that he knew the Paper but he did not know why it had disappeared from the literature, and why its influence had not spread.

Mr. Fawdry said that the design of a model entailed an impact on real situations. Could he be guided as to the actual journal which dealt with some of these problems and was called *Impact*; where could he find such information ?

Dr. George replied that the *Impact of Science on Society* was a Unesco publication concerned with social, scientific and historical problems.

Another speaker referred to information issued in August, 1957, he believed in *The Times*, which contained a full summary of Papers on queueing, including some by Cox and Bennett.

Mr. Fawdry asked whether these methods had been applied to transport problems — depots, routes, frequencies and so on.

Mr. Harling said this was a particular case of linear programming and there was an extensive literature.

Mr. Novelsky asked whether there was any guide to the literature on operational research and cybernetics, so that if one had a problem one could find out whether a similar problem had already been solved.

Mr. Harling said there was no guide. There were journals such as the Operational Research Quarterly, the Journal of the Operation Research Society of America and one or two textbooks. One should keep away from the " cook-book " point of view in operational research. No two problems were exactly the same in his experience.

Dr. George said that the International Institute on Cybernetics would be publishing later this year a complete bibliography on cybernetics which would give every reference to cybernetics and operational research up to the end of last year. This might be a starting point. It would not be a cook-book but it would be a guide to cook-books.

The **Chairman** said it was his pleasant duty to thank the two lecturers very warmly for providing such excellent mental material. He did not propose to give a summary of the meeting, but only to throw a couple of spanners into the works.

It might be possible to make machines act in the same way as human beings. It might be possible to determine many things scientifically and produce mechanical answers. In the long run, it was surely people one was thinking about. In the long run, one must recognise that 75% of all industry in this country was concentrated into units of less than 100 workpeople. Many of these units would have neither the imagination, education or financial capacity, or the managerial vision to benefit by the blessings of mathematical science in these particular forms. He would leave it to the two lecturers and the audience to decide whether this meant that these poor folk — and they were 75% of the industrial population — were going willy-nilly to be sponged off and a machine was going to do the work for them; that was to say, whether industry was going to be agglomerated into enormous and possibly de-humanised units. He did not like the thought.

In the long run, science had to be the handmaid and could never be the taskmaster. Science must serve humanity and humanity's desire for happiness, for full living. And full living did not necessarily mean the understanding of complex and mathematical formulae.

Those were surely the objectives of all serious work in all serious fields, and he hoped nothing the two lecturers had said would lead anyone to suppose otherwise.

He would also like to suggest that however mechanised one became, there was a certain glory in craftsmanship. There were wonders of the world which were beautiful not because they were mechanical, and one must try to preserve the balance and keep a reasonable view of life and all its wonders.

He was an ordinary business man, not a scientist or a mathematician. He had come to the present meeting partly out of a sense of inquisitiveness, because he had heard learned gentlemen both in this country and overseas talk on the subject of cybernetics and operational research. They had always left him somewhat bewildered. He had also come out of a sense of duty as Chairman of the British Institute of Management. He had had a sort of crinkly feeling down his backbone that it might be exciting. He was very glad that he had come, because he was left with a sense of excitement in a more practical way than before. These two gentlemen had given him something that opened up a future which in many ways, properly controlled and balanced, was tremendously exciting. But although he was glad, in some ways, that he was an old man, he could wish that it might be possible to get a machine to reproduce himself so that he could go on for ever.

In thanking the lecturers, he would also thank those who had contributed to the discussion.

The vote of thanks was carried with acclamation.

OPERATIONAL RESEARCH

CASE STUDIES

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MANAGEMENT TRAINING IN THE U.S.A.

a review of teaching techniques and teachers

by GORDON F. HIRD

Mr. Hird was educated at Altrincham Grammar School, Cambridge University, and Exeter University, and has had experience in iron and steel, engineering, and a nationalised industry.

He entered education seven years ago and for the past four years has been Senior Lecturer in Management Studies at the Newcastle College of Commerce. He is now mainly concerned with courses in management development and work study.

In 1957, Mr. Hird was one of a group of eleven Europeans invited by the E.P.A. to visit centres in the U.S.A. to study the organisation of courses in business administration and methods of teaching.

DURING the past 50 years, training for management has become an accepted activity in the field of education in the U.S.A. The movement, which was already firmly established before the Second World War, has gathered momentum during the past decade. Management is not a profession, to the extent that every man and woman with an executive position has a nationally accepted qualification; but an increasing number of managers at all levels have either a degree which includes at the minimum a number of subjects in business administration, or have passed through one or more of the many short courses being offered.

In this movement the formal centre for higher education, the college, was early in the field and by the turn of the century three colleges in America had accepted management as a study worthy of serious consideration. By the beginning of the First World War, 30 colleges had introduced departments concerned with business administration. Today the colleges with degree courses can be numbered in their hundreds, the degrees obtained annually in their tens of thousands, and the students attending at any one time in their hundreds of thousands. They range from the famous such as Harvard and Cornell, with their exacting standards, to the lesser known ones which set their sights lower. It is difficult to compare these colleges with educational establishments in the U.K. In many the intellectual standard compares favourably with the standard required for an honours degree in Britain; at others the standard is far lower. But as will be shown later, most schools of business administration in America are concerned with many skills and abilities, and not merely with the intellect.

In addition to providing courses leading to degrees, about 50 of the leading colleges have management development programmes for established executives. These may be anything from one day to one year in length and may cater for the junior manager or the managing director. They may have the aim of

making a man more effective in his particular field, for example, salesmanship or industrial engineering, or of giving the senior department manager the skills and knowledge he will need as a general manager.

Although most of the work being done in the U.S.A. is full-time and during the day, many of the colleges organise work in the evening leading to the award of degrees. To obtain a degree this way may involve 10 years' of successful study. Lecture courses are also organised for executives seeking specialised knowledge, and who have only limited time to spare. As with colleges concerned with evening education in this country, many problems are faced in this field and the wastage rate is high.

Industry itself is also actively engaged in "in-plant" management training and there are probably 300 to 400 firms running well defined programmes. As with management, development programmes in college courses can have different aims and can vary in length. One or two of the leading firms in the U.S.A. have research sections which are engaged in fundamental management problems. The work being done at the Bell Telephone Laboratories in New Jersey is of this type.

Management training is provided by various groups of individuals and firms working in association. One of the best known is the American Management Association, which is a non-profit making body centred in New York. The Association attracts to its many courses each year over 60,000 established executives from industry, commerce, the Church, Government bodies and the armed forces. These courses are of fairly short duration, ranging from one day to one month, and classes vary from large to small, according to the work being done.

As will be appreciated, the above is a somewhat perfunctory survey of the organisation and scope of courses in management training in the U.S.A. However, it indicates the amount of work being done and the way in which management training is accepted as an important part of the American scene. It is established and it is respectable. There may be disagreement about its scope and who should undertake it, but industry and commerce are fairly unanimous on the need for management training of some type.

variation in techniques

Given such a wide range of activities in the management training field, as might be expected there is great variation in the teaching techniques used. Further, most American teachers aim further than giving information and training the analytical minds of their students. They are concerned with developing such specific managerial attributes as the ability to work with people, the ability and willingness to make decisions, the development of integrity and a sense of responsibility for the chosen vocation. These factors alone would encourage the development of teaching techniques of a range and type far beyond what the aims of a more conventional course might demand.

The formal lecture method, that is, when a lecturer comes in at a specific time, talks for his allotted 45 minutes or more and then departs, is seldom used at all in the U.S.A. in the management field. An approach of this type might be seen only at the opening or closure of a course. Most American teachers would agree that with this method there is too great a gap between the teacher and the taught and that, with some exceptions, the material of the lecturer could be better derived from the printed word. Also, the formal lecture followed by questions from students and discussion is seldom employed, and then only when a visiting speaker is talking on his specialist field.

the "interrupted" approach

The "interrupted" lecture approach is used a great deal on courses. With this method, a teacher covers one aspect of a course and then is either asked questions or invites comments. It is possible that an "interruption" comes every 10 or 15 minutes according to the subject, the attitude of the teacher and the interest of the class. This technique, which is the usual method found in British technical and commercial colleges, is probably more used in the U.S.A. than any other.

However, there is a wide range of techniques in the U.S.A. which are unlike those usually found in the U.K. The student often takes a very active role in the classroom and the success of a technique may depend on this student participation. One such method that has become internationally known in management training is the case study method, which is used almost exclusively at the Harvard Business School of Administration, probably the leading college concerned with management training in the U.S.A. A case is either a real or "armchair" report on one aspect or more of a firm's activities and may cover information on production, finance, development and design or sales. The paperwork describing the case is usually from 5 to 50 pages in length and includes all the relevant documents. For example, a production case might give details about the plant and equipment, statistics on output and costs, and verbatim conversations of the people involved.

Students first discuss a case informally in groups of about 10. There is no attempt to get a group attitude, but this gives them the opportunity both to formulate and express their views. Students in residence may do this preliminary work on the day before the class meeting in the rooms of one of the group; married students living in nearby Cambridge are often obliged to cut things finer. When the full class meets there are up to 80 men in the group in classrooms where the seats are arranged in tiers. Most full class sessions last 1 hour 20 minutes. During a typical week in the 32-week year, which is divided into two terms, a student studying for the M.B.A. degree has to cover about 20 cases from the Harvard library of 20,000. In addition he is doing a certain amount of written work on cases. His first main class meeting may be at 8.40 a.m. and it is often midnight before he is through the informal sessions and pre-

pared for the following day. As can be seen the pressure on a student is considerable, but it is considered that he is being prepared for a stern, competitive world and this is his apprenticeship.

During the main class session the teacher guides discussion on the case, summarises stages, questions and probes, and brings students to a point of decision. He does not interject his own views and does not give a " correct answer " at the end of the case. Although no two lecturers have an identical approach, there is a Harvard philosophy and most of the 20 or so sessions I observed followed a similar pattern. As a result of students keeping in the same seats, and the teacher having their photographs and names in front of him, he is able very early in the year to wield complete control over what to British teachers would appear to be a very large group. The class session is seldom dull and in spite of the large numbers about half the students participate. American students often base their arguments on practical points. In one case which involved a type of camera a student, who wanted to make the point that the firm should spend more on research before it expanded its sales campaign, brought a camera into the classroom, took photographs and passed them round the group, in order to emphasise his comments.

the case study method

The aim of the Harvard Business School is to develop those qualities which are essential in successful administration, and this it believes can best be done with the case study method. In particular, case studies are meant to achieve three objects :

1. To develop the decision-making aspect of management in a student. To achieve a decision, evidence has to be marshalled and then subjected to a man's close analysis. When a student makes a decision it is tested against the ideas and views of his fellow students. Having to reason and make a case before such a critical group is in itself a training in management.

2. To create as near a business situation as can be done in the classroom. It is a manager's apprenticeship, and just as a trade apprentice is taken through certain graded steps so are management students, for the information and knowledge involved in a case, whether it be accountancy or production engineering, is increased during the period of a course.

3. To create a situation where the burden of learning is on the student and from which he himself can develop useful generalisations. It has been said that Harvard is " happier if students find out for themselves a principle which has been known for 50 years, rather than discover a brand new principle ".

The critics of the Harvard approach claim that a student has no exercise in discovering information — it is all there or not available, and this lack of action is not typical of the business scene. Further, it is said that many students have only glanced through the case and try to pick it up as they go along, and that the people who have read it tend to dominate the others. An additional criticism, which, of course, can be levelled at all classroom teaching of this type, is that it does not represent an actual business situation as there is an absence of real responsibility.

To the best of my knowledge, it is only at Harvard that the case study method is used in the way that has been described. Harvard states that this " pure " case study approach is not of value on short courses and that a number of weeks may have to go by before the student is reacting in the way they wish. An additional point that could be made is that it may be only really successful with students of the calibre Harvard is able to attract.

Case studies compiled by Harvard are sold to 300 other establishments interested in management training and these are used in a variety of ways. At another leading college in the U.S.A., Harvard's case studies are used for about 30% of the teaching time, with other techniques completing the classroom sessions. In the case study classes, groups would generally be smaller than at Harvard and there would be much stronger participation by the teacher, with criticism at the end of the period and an " answer " given.

A technique which claims to have the advantage of the Harvard case study method and also to develop training in asking the right questions, which the originators, Paul and Faith Pigors, feel is a vital attribute in a manager, is the Incident Process Method. They believe that this method combines analysis and action, encourages the student to avoid snap judgments and develops a respect for facts, as well as the ability to work with others.

the Incident Process method

Each incident session lasts about two hours and there are five main phases. First, a written incident of a situation involving a human problem is handed out to the 20 or so students, which is considered to be the best number. The incident in 50 or 100 words gives brief details about a situation that has arisen and the student studies it with the aim of deciding : What is going on here ? What is the issue ? What facts do I need before getting down to making decisions ?

This phase lasts about five minutes and then students ask the group leader for any further information they may require. The stress is on eliciting facts from the leader — what ? where ? when ? who ? how ? — and not on evaluating. The team leader gives information only when he is asked for it, and this may be in the form of verbal answers, or if it involves agreements and reports it will be in writing. From his own and other people's questioning a student builds up his own case, just as it is considered he would do in practice. The experience of Professor Pigors is that a group of senior executives " crack a

case " in 30 questions — at the rate of four questions a minute; undergraduates take considerably more questions.

At the end of this phase one student summarises the facts of the case as they appear to him. Students dislike doing this and there is often disagreement as to what has been said — a situation which isn't unknown in industry. The summary is the bridge-head to decision-making. The main issue in the case and the sub-issues are clarified and students make a written decision on each issue and give their reasons. These written decisions are passed to the group leader and sorted. It is usually found that the decisions on the main issue can be placed under one of two or three headings — in a situation the alternatives might be to dismiss the man : to suspend him : to do nothing. Students with the same decisions are segregated and sent to separate rooms where they each elect a spokesman to develop the group's strongest case. The aim in this fourth phase is to show that a group's case is invariably better than that of any individual. When all the students are together again the spokesman from each group presents his case to the main group.

In the final phase students are told what happened in practice. A general discussion is then held on the session. Were enough facts obtained ? Were some of the questions asked superfluous ? Was the decision right on the evidence available ? What have we learned from the session and what principles can be drawn from the case ?

The Incident Process Method is of much more limited scope than the Harvard approach or the approach developed by organisations using Harvard cases. However, in this more limited field it can be argued that it does tend to give a fairly accurate reproduction of the business scene, to the extent of stressing the need of asking the right question and getting the facts before coming to a decision.

the Living Case method

Another technique which is used at the School of Business Administration at Washington University in St. Louis is the Living Case Method. The aim of this approach is to bring problems facing the business community at the time into the classroom and to give students the stimulus of dealing with actual situations.

The first step is to find a firm willing and able to co-operate. Having overcome this hurdle, it is probable that the firm's first contact with students is through one of the company's executives presenting information on the history, the major policies and operations of the organisation. This is followed by reading material on annual reports, policy manuals, employee handbooks and other company materials which can be gone through at the students' leisure. Before this background period is completed, students may be taken round the factory and office and shown the physical situation.

The next stage is a panel discussion by a group of the company's executives and general management, sales, production, finance and personnel may be represented. During this discussion current problems and policies are brought to light, and from this information and questions answered students build up their own case. Later, the class and the teacher work together analysing the information they have received.

Each student writes a complete report on his appraisal of the company studied. His detailed report covers the company as he sees it, an analysis of the problems and the steps he recommends should be taken. This final report is seen by the teacher and whenever possible by the executives of the company, who comment on it.

It is claimed that for young college students the Living Case Method has most of the advantages of studying written cases, and much is gained by using up-to-date situations and problems which are currently being solved. The student has a better learning experience when he is required to seek out facts in discussion with business executives, in observation of company operations and from written work supplied. Further, the student has the experience of dealing with business executives and gaining an indication of their " know-how ". Two difficulties of the Living Case Method that come to mind are that there is the problem of obtaining satisfactory firms to co-operate, and then ensuring that executives are really giving facts and not merely their interpretation of the situation. It might be mentioned that the industrialists taking part find it a stimulating experience to have to present information and then to justify their actions and decisions when questioned by students. The Living Case Method is used only a small part of the time on courses at St. Louis.

Business War Games

Of the various courses organised by the American Management Association, one of the most interesting is the Business War Games course for executives. The aim of the course is to develop the decision-making aspect of management. Most executives learn decision-making by practising it on the job. But this has its limitations as few specialists, for example, have the opportunity to make decisions on an overall company basis, and this course has the senior executive in mind. Further, few executives have the opportunity, once having made a decision, to see the effects of it, and to be able to consider whether it was a good decision, and if not why. In the A.M.A.'s Business War Games course, teams of players, who are in competition with each other, make the basic decisions of the kind that face every top management and see the results immediately. The game is specifically designed to provide conditions under which a few hours of concentrated decision-making under pressure will simulate years of business experience.

In the game, players are divided into four or five teams of companies. All companies are assumed to

be manufacturing the same product and only that product. The game opens with a distribution of the initial operating statements to the teams. The report lists such factors as the company's total assets, number of units of plant capacity, unit cost of production, price of product, opening inventory, cash in hand, and percentage of a given market controlled by each company. Each team is given a fixed amount of time to make its decisions for the coming quarter. These include such factors as additional plant investment, research and development, production costs and the price to be charged for its product. In addition to their basic decisions the players can buy market research information and sell plant to raise cash.

At the end of the first decision period, the marked sheets are collected and turned over to a key punch operator. One punched card for each team is fed into an IBM 650 electronic computer, which in about $2\frac{1}{2}$ minutes computes the effects of every team's decisions on every other team's position and punches out a deck of output cards. These cards are processed through an IBM 407 printer, which prints the quarterly operating sheet for each team. These reports are distributed and after reviewing its performance during the last quarter each team makes fresh decisions for the next quarter.

Students in the War Game face problems like those met by top management in daily business. They are forced to do strategic planning. They have to decide — Should we spend on research and development ? Should we try for high volume at low margin, or turn out a high quality product at a high price ? Are we going in for price cutting ? The game demonstrates the complexity of running a modern business and it is hoped that it makes the point that management by rule of thumb is no longer the most effective way of controlling.

These techniques are only four of the approaches being used in management training in the U.S.A. There are others, including the Consultant Case approach at Indiana University and the Project approach at Massachussetts Institute of Technology, which are unfamiliar in England; as well as some that are to be seen over here, such as syndicates.

teaching techniques

It is difficult to describe teaching techniques without at the same time saying something about the teacher. It would seem to me that the place of the American full-time teacher of management differs greatly from that found in the U.K. The American teacher has often one foot firmly placed in industry, as well as one in education through consultancy work. There are a number of advantages that can be claimed for this approach.

It can be argued that it encourages first-rate executives to transfer from the industrial to the educational world. American management teachers are probably relatively slightly better paid than their counterparts over here. As there are no national scales for teachers in the U.S.A., it is not possible to give precise figures. However, from investigations conducted by the American Association of University Professors and from the reports of the United States Office of Education, it appears that at the present time salaries range from \$7,000 to \$20,000 per annum for a full professor, and about one-third of all college teachers have this designation. (To put these figures into perspective the earnings of production workers in manufacturing industries are in the region of \$4,000 per annum.) The pay of the professor will depend on the institution, his own ability and his length of service. However, an exceptional man with a skill which can be used by industry or commerce may double or treble his academic salary by consultancy work. In other words, education has a financial carrot to offer to some of the most able executives in industry.

additional advantages

Additional advantages which can be claimed for encouraging consultancy work are that industry has more faith in courses taught by people who practise what they preach. If a teacher is able to improve the efficiency of a concern, then top management will be more favourably disposed to releasing people to attend courses. He is, in fact, acting as a salesman for the college he represents and building a link between the educational and the industrial worlds. And, lastly, it can be said that a man who is constantly refreshing his experience in the field is a better teacher. A man who has recently introduced a new layout, or a time study scheme, will be a more stimulating teacher than a man who draws his knowledge from a book or his experience gained in the dim, distant past.

The American college teacher has usually between a 6-hour and a 12-hour teaching week and 9- or 10-month year. Indeed, for a college to be accepted as a member of the American Association of Business Schools, teaching hours have to be limited to 12 hours a week, which is reduced for teaching to senior students. Further, in most colleges the teacher is adequately supported by laboratory and secretarial assistants, who relieve him of the need to be a mechanic - cum - shorthand typist - cum - telephone operator, and enable him to concentrate on the work for which he is appointed.

Visual aids and the equipment used are usually of a high quality. At a centre like the A.M.A., each room has a sound projector, artificial light only is used and windows are blocked out to sustain concentration, and in the main lecture hall a teacher may have a trailing microphone, a " vu-graph " and pre-prepared summaries, which appear almost as if Heaven-sent from the ceiling. In other countries dealing with undergraduates facilities are seldom on this scale, but the atmosphere is often congenial for adult study and there is an absence of petty restrictions. For example, smoking is usually allowed during classes and there are breaks from time to time when students can obtain refreshments.

As in the U.K., a number of bodies in the U.S.A. employ part-time teachers from industry and commerce. It is very difficult to generalise, but there is every indication that executives in the U.S.A. feel a sense of responsibility for the local college, and are more willing to give their services in this way than often happens in England. An interesting point is that part-time staff are usually paid less than full-time staff for teaching at a particular level.

As may well be appreciated, this survey of teaching techniques and teachers cannot claim to portray accurately the whole of the American scene. There are so many courses and so many different techniques in use. To see them all and to gain an insight into their methods and aims would take considerable time. Further, the status and work of the teacher varies appreciably from centre to centre. However, undoubtedly some factors appear constant. There is in America a basic belief in management training and a close connection between industry and education, in which the teacher plays a key role. There is, too, the receptiveness of educational bodies to new teaching techniques and the conditions necessary for their application.

What, if anything, can we in Britain learn from American experience ? It can be argued that there is a direct connection between the level of efficiency and the satisfaction to be gained by all involved in industry, and the standard of management. Further, that though some of the abilities required for management cannot be trained by any course, many of them can. That though job knowledge and experience are, of course, essential and can never be replaced, other abilities are required for effective management and satisfactory training can equip a manager with some of the tools he will need.

There is at the present time an ever-increasing interest in management training in England, and there is a widening number of courses available. If this form of training is to become an accepted and successful feature of the British scene, as it is in America, it would seem that certain conditions have to be satisfied, including the following. First, from the teaching establishment's point of view, able teachers have to be recruited and retained. This is true whether the teaching is done in industry or by academic establishments outside industry. These teachers preferably should have had wide experience at a senior level in the field in which they are going to teach. Their experience should be renewed frequently. Second, the teaching establishments should provide conditions in which teachers and taught can both do their work satisfactorily. This is not solely a question of elaborate equipment and surroundings, though both have to be of a reasonable standard. Lastly, the aims of courses should be fairly well defined and teaching techniques used that are based on the needs of the situation and not merely on tradition.

DIARY DATES

1958

OCTOBER 13th, 14th and 15th
Materials Handling Convention, Brighton

OCTOBER 29th
Annual Dinner of the Institution, Dorchester Hotel, London.

DECEMBER 11th
The 1958 Sir Alfred Herbert Paper, to be presented at the Royal Institution, London.

Speaker : **Sir Cecil Weir,** Past President of the Institution.

Subject : **" The European Common Market — Its Origins and Implications ".**

1959

MARCH 11th
The 1958 Viscount Nuffield Paper, to be presented at the University of Birmingham.

Speaker : **Dr. N. P. Inglis,** Metals Division Research Director, I.C.I. Ltd.

Subject : **" The Production, Fabrication, Properties and Uses of Some of the Newer Metals ".**

EXTRACTS FROM

REGION AND SECTION REPORTS

Presented to Council, 24th July, 1958

EAST AND WEST RIDINGS REGION

Leeds

The Annual Dinner of the Leeds Section was held at the Griffin Hotel, Leeds, on Saturday, 12th April, 1958, and was graced by the presence of the Lord Mayor of Leeds, Mr. Gregory, Chairman of Council, and many other distinguished guests.

It was agreed by all who were present that it was a very successful Dinner, and the speeches and entertainment were of the highest order.

The Leeds Section made the arrangements for the George Bray Memorial Lecture which was held at the University of Leeds on Monday, 24th March, 1958, when Dr. Yarsley gave a paper on " The Fabrication of Plastics."

The Paper was very well received and a very full and informative discussion completed the meeting.

The Leeds Section and the Institution suffered a great loss in the passing of Mr. F. T. Nurrish, M.B.E., a past President of the Leeds Section, a past President of the East and West Ridings Region, a member of the Council and on the Council of P.E.R.A.

Mr. Nurrish had been a member of the Section since its inception, and over the years had been one of its strongest supporters. His advice and guidance were always available to the younger members, and his presence will be missed by all the members and Committee at our meetings.

Leeds Graduate

The Section Committee have held a number of meetings within the past few weeks, devoting a good deal of time to the preparation of the Section Programme for session 1958/9. A provisional programme has now been drawn up as follows:—

1. Works Visit to Messrs. Samuel Fox Ltd., Sheffield.
2. Works Visit to Messrs. British Jeffrey-Diamond, Wakefield.
3. Film Show in Leeds.
4. Works Visit to a glass fibres factory.
5. Works Visit to Messrs. Slazenger, Wakefield.

The Committee did consider extending the programme, but after considerable discussion, decided that in general far too many meetings are arranged, particularly since the Leeds Graduate Section are always invited to attend lecture meetings held by the Leeds Senior Section.

Sheffield

The Section's representative on the Materials Handling Group Committee presented his first report to the Section Committee, during which he outlined the principal objects of the Group. Arrangements have been made for him to speak at a lecture meeting, to give details of the Group's aims and activities, in an effort to stimulate further interest and to encourage the enrolment of suitable members. It is hoped to arrange an informal meeting of interested members, to discuss and formulate a programme.

The Lecture programme for the winter session is now completed, and includes a lecture meeting organised jointly with the Institute of Welding, and a Regional Paper on " Ergonomics."

One or two members of Section Committee were honoured to meet, at a dinner, members of the Polish Society of Mechanical Engineers who visited this country recently.

EASTERN REGION

Ipswich and Colchester

Since the last quarter, the Section enjoyed an extremely interesting evening at Colchester, when a Paper was presented by Rear-Admiral R. S. Warne on " Work Study as a Service to Management." This was preceded by the Annual General Meeting and brought to a close the winter lecture programme.

During May, a party of 20 members made an afternoon visit to Bradwell Power Station in Essex and as this is in the building stage, it was most interesting to see the amount of equipment necessary to carry out such a large project.

A further evening visit has been arranged during June and members of this Section have the opportunity of seeing the works of Messrs. Ransomes and Rapiers Limited, Ipswich.

The Committee is now planning a visit to London Airport during September, and it is hoped this will prove an attractive event to members and their friends.

The Committee are pleased to mention that representation was further strengthened when Mr. S. H. Potter, B.Sc., A.M.I.Mech.E., A.M.I.Prod.E., filled a vacancy when he was co-opted to the Committee during May. Mr. Potter is Head of Engineering and Science Department, North-East Essex Technical College.

MIDLANDS REGION

Regional Report

The Regional Dinner was held in April at the Queen's Hotel, Birmingham, and was judged a complete success. The speakers included Sir John Eldridge, Sir Cecil Weir, Major-General K. C. Appleyard and Mr. S. M. Barker. The civic representatives included The Lord Mayor of Birmingham and The Mayor of Worcester. The Regional Honorary Secretary reported a slight increase in the number attending, thus indicating further growth in the local interest in this function.

The Regional One-Day Conference was held in May at the works of Cincinnati Milling Machines Limited. Four very well presented papers on subjects ranging from hot machining and electro-discharge machining, flow-turning and hydraulic forming, to computer control of machines, were given to the Conference's theme—" Machining—Tomorrow's Production." The President's address—" The Machine Tool in Industry " was most inspiring to the delegates and gave voice to advanced thinking that must be applied to the future problems of tomorrow's production. The delegates were then able to see many working examples of latest machining techniques and machine tool building in the adjoining plant.

The suggested programme for the 1958/9 session has been discussed and meetings of high calibre are the keynote, and a One-Day Conference to round off the Regional Programme will complete the pattern.

Mr. H. Tomlinson, former Chairman of the Wolverhampton Section, has accepted the nomination for Chairmanship upon the retirement of Mr. B. G. L. Jackman.

Mr. T. W. Elkington, Past Chairman of the Birmingham Section, has been nominated Additional Regional Representative to Council, upon the retirement of Mr. E. Percy Edwards.

Birmingham

The last lecture of the Birmingham Section session was held in March and dealt with two recent developments of the use of plastics in metal-working. The first, by Mr. Pentz, of Leicester, Lovell and Company dealt with the use of press tools made from various types of plastics. Particular applications were described in detail and as many questions as the time allowed were interestingly dealt with. Mr. Hulbert, of Scott Bader and Company, then gave some information on various alternatives to sheet metal which had been tried and approved in production, quoting many interesting examples from both sides of the Atlantic.

The charter flight to the Brussels Fair, held in May, was very much enjoyed by those who attended, and it was noticed that the charge was only two-thirds of that being advertised for similar trips travelling at the same time. The Section's thanks are due to the travel company, who arranged to fill the aircraft themselves when approached by Mr. Lawton at short notice.

There will be a Summer visit to the English Electric Company, Stafford, and Ingestre Hall, in June. The Company have very kindly offered lunch at their premises and the interest and help from them gives promise of a very interesting and pleasant visit.

Birmingham Graduate

The lecture on product design and the visit to the Cincinnati Milling Machine Company, both of which took place in May, were well attended, and this has given rise to some satisfaction, particularly to those members of the Committee whose job it is to strive towards giving the general body of members a well balanced and interesting programme of visits and lectures to choose from.

In the coming session, which coincides with the Section's 25th consecutive year of existence, the Committee feel that it is fitting to arrange something special by the way of celebration. The programme is not yet finalised, but all members will become acquainted with it in the near future, and the Section looks forward to the continued support of members and friends in this coming 25th year.

At the Annual General Meeting held in March, Mr. D. J. White was elected Chairman and Mr. R. V. Wateley was re-elected Honorary Secretary for the 1958/9 session.

Coventry

Another most successful session terminated with a Regional Lecture held in the Sibree Hall, Coventry. This lecture was so well publicised that nearly 1,000 applications from all parts of the country overwhelmed the organising committee and many applicants were unavoidably disappointed. Approximately 400 visitors and members listened to a most interesting report on " Ceramic Tools " presented by Mr. H. Eckersley, M.I.Prod.E., and Mr. R. M. Cook, M.I.Prod.E., both of Wickman Limited. The report was illustrated by slides and film, which included the latest available information on the results of the use of ceramic cutting tools both in this country and abroad. A searching discussion followed and many questions were admirably answered by both lecturers.

The Annual General Meeting was quite well attended. The Committee accepted with regret the resignation of Mr. B. C. Harrison, M.I.Prod.E., a former Section Chairman. Mr. Harrison may not however, be lost to the Institution as an active member, having been nominated by the Section for election to the Council.

A departure from usual practice was the showing by courtesy of the Standard Motor Company, of two delightful travel films (" Through Central Europe ").

NORTHERN REGION

Newcastle upon Tyne

The Annual General Meeting, which was held in April was well attended. Following the meeting, Mr. J. S. Elliott, Principal of the Rutherford College of Technology, Newcastle upon Tyne, kindly arranged for the members to visit the new workshops and laboratories, showing the recent development of technical education facilities in Newcastle upon Tyne.

The programme for the session 1958 - 1959 is now completely arranged and it is suggested that a Section Programme be circulated to the Members within the Region, thus avoiding the delay which is at times encountered in compiling a programme for all meetings within the Region.

Tees-side

This quarter has seen the completion of the winter lecture programme, which has proved to be the most successful to date in spite of the exceptional weather in the early part of the year, when during two of the lectures, many roads were snow-bound.

The Committee are especially pleased with the number of applications for membership coming forward.

The first works visit has taken place, during which Mr. Williams of Messrs. Williams and Williams, Chester, presented the Section with a Chairman's Chain of Office.

NORTHERN IRELAND REGION

Northern Ireland

During the period covered by this report, two Section functions were scheduled. Dealing with the second first, a lecture on " Work Study " by Mr. A. J. Speakman, was arranged to take place in April. Unfortunately, due to circumstances outside anyone's control, this lecture could not take place.

In March, the Annual General Meeting was held, and as an innovation, was preceded by a Section Dinner and followed by a social evening.

This function was well attended and would appear to set a precedent for future Annual General Meetings.

At the conclusion of the meeting, the retiring Chairman, Mr. K. Teale, gave an address, taking as his subject " The Production Engineer, His Present-Day Standards and Industry's Future Requirements." The resulting discussion absorbed the major part of the remaining social evening.

NORTH MIDLANDS REGION

Regional Report

The main item in the Region was the One-Day Conference in Leicester in June. The theme " Foreign Competition—The Challenge " was a topical one and attracted members from far beyond the boundaries of the North Midlands Region. The organisers kept foremost in their minds the young man meeting foreign competition for the first time, and the ways in which Britain can combat the intrusion.

Delegates were accompanied by their ladies, for whom an excellent itinerary had been prepared and the Conference upheld the high tradition which has already been established in Peterborough and Lincoln.

Lincoln

The attendance at Section lecture meetings has been maintained and the attendance at the Annual General Meeting, which was held towards the end of March, was very good.

At the Annual General Meeting, Mr. Oram was thanked for his services as Chairman of the Section during the last two years. He will be succeeded by Mr. J. Cunningham, Director and General Manager of the Boiler Division of Ruston and Hornsby Limited.

The Section Committee are now preparing their programme for the forthcoming winter session. They have suggested four lectures, apart from the Annual General Meeting and the Annual Dinner Dance, which has already been fixed for November, at the Saracen's Head Hotel, Lincoln.

It is with regret that Lincoln Section Committee have to report that they have lost the services of Mr. E. Burgess (Managing Director of Marshalls, Gainsborough).

Loughborough Student Centre

During the last quarter, only one meeting took place. This was the Annual General Meeting which was held in March in the Brockington Building, Loughborough College. Twenty-one members were present and an apology was received from one other. The following officers were elected: Chairman, M. C. Fryer; Vice-Chairman, A. J. Booth; Secretary, J. Fairbrother. The following Committee Members were elected; I. Anthony; M. H. Hanson; B. V. Hubbard; J. G. Loveday;

H. Maden; A. Roberts; L. Rodwell; J. W. Scott; D. R. Stockdale.

The future programme was discussed, mention being made of works visits and of films.

Nottingham

The summer activities of the Section started with a most interesting visit to a glass works in Worksop, when members had an opportunity of examining the production of all types and sizes of glass bottles. After the visit, members were entertained by the Company to an excellent luncheon.

The Section Committee have nominated Mr. C. T. Butler, Head of Mechanical Engineering, Nottingham and District Technical College, as their representative on the International Standards Sub-Committee. Mr. Butler is also the Section representative on the City of Nottingham Library Advisory Committee, which enables members of the Section to borrow an extensive range of technical books on production engineering.

NORTH WESTERN REGION

Regional Report

The North Western Regional Lecture was held in April in the Great Hall of the Manchester College of Science and Technology. The Rt. Reverend Dr. W. D. L. Greer, Lord Bishop of Manchester, spoke on the subject " Human Problems in Industry."

Mr. J. Jones, M.P., J.P., opened the discussion, which was of a very high standard, and most informative.

An Inter-Section Golf Tournament is being arranged to compete for the " Regional Challenge Trophy " and the response to the Honorary Secretary's circular has been most encouraging.

Lecture programmes for the Sections are now being arranged, but the Secretary would remind Sections that the programmes should be forwarded to Headquarters as soon as possible, so that the programme syllabus booklet can be printed in time for the first lectures.

Manchester

The lecture programme for 1957 - 58 is now completed and it is encouraging to note that more members are attending meetings than last year. The lectures which had the greatest attendance were " Photography in Engineering " and " Machine Tool Development in the U.S.S.R."

The Section Syllabus Sub-Committee have submitted a most interesting number of lectures for the 1958 - 59 session.

The Annual General Meeting was held in March and although the Committee would like to see more members attending this important meeting, it was very encouraging to see a big improvement on last year's attendance. The Section welcomed Mr. F. W. Cranmer, who is to take the chair once more for 1958-59 and Mr. J. P. Speakman who will continue as Honorary Secretary.

Preston

The 1957 - 1958 lecture programme proved very successful, attendances showed a decided increase and greater interest was generally evident. The programme concluded with two excellent lectures, " The Electronic Control of Machine Tools " by Mr. D. T. N. Williamson, at Barrow-in-Furness, and " Himalayan Adventure " by Mr. K. J. Miller, who gave a graphic description of his personal experiences as a member of the Imperial College Scientific Expedition to the Himalayas.

Section members are reminded that the Section representative to the Materials Handling Group is Mr. H. Carleton of 95, Liverpool Road South, Burscough, Lancs. (Tel. Burscough 3321), and he will be pleased to supply information regarding any aspect of this important branch of production engineering.

Mr. T. A. Westall and Mr. G. H. Ayres, two valuable and active members of the Preston Section, have recently retired from their employment and the Section Committee and members wish them well.

Mr. Westall is a past Chairman of the Preston Section and has been honoured by the Institution by being granted free membership in acknowledgement of his long and valuable service to the Institution.

It is with profound regret that the Section has suffered a great loss in the sudden death of Mr. E. G. Eaton, a past Section Chairman, and he will be missed by many.

SCOTLAND REGION

Dundee

The Section has been troubled in the past with a surfeit of technical lectures sponsored by the various associations in the district. This has often resulted in poor attendances at Institution meetings, partly due to the clashing of dates.

To try and overcome this difficulty, a meeting of Institution Secretaries was called under the auspices of the local Productivity Committee. The following rules were drawn up and have been accepted in principle by the Institutions concerned:—

(a) Each Institution has been allocated a particular day and week per month for their lecture meetings. This will ensure an even spread over the month and will avoid clashing of dates.

(b) Wherever possible, Institutions are to arrange joint meetings with other Institutions. This will reduce the number of meetings.

(c) One joint meeting with all other Institutions is to be held in December. This will reduce meetings in a month which has a high percentage of social functions.

Edinburgh

No report received at the time of going to press.

Glasgow

In February, the Section was privileged to have the Rt. Hon. The Earl of Halsbury present his address to the Section. Over 100 members and visitors attended the meeting, which was held in the Rankin Hall of the Institution of Engineers and Shipbuilders. During the day, the President had visited certain factories in the area, together with the Chairman and Vice-Chairman of the Section, and prior to the meeting had dined with the Section Committee.

The first of two factory visits was to the Queens Park Works of the North British Locomotive Company in May. The visit proved most instructive and there was a good turnout of members.

At the Section Annual General Meeting, Mr. G. V. Stabler was elected Chairman for session 1958 - 1959. Mr. Wilson tabled his resignation at this meeting and in accepting this the Chairman thanked him for his long service to the Glasgow Section.

The Committee met five times during the Session and on each occasion there was a very full agenda. The number of applications considered has been most satisfactory and it has pleased the Committee that many of the candidates are technically qualified and eligible for election.

The Regional Committee has met on two occasions and at the last meeting, Mr. MacKay, Dundee Section Chairman was elected Regional Chairman for session 1958 - 1959. The Committee have given consideration to the holding of a Scottish Conference, but do not feel it justified at the present. The matter will, however, be kept under review from time to time in light of changing conditions.

Whilst the distance between each town prevents the Sections in Scotland operating as a Region, there is no doubt that the Committee Meetings have proved most stimulating to the representatives and many problems common to all Sections have been openly discussed. Section representatives have gained a great deal by attending and there is no doubt that the Committee Meetings have fulfilled a useful purpose.

SOUTHERN REGION

Oxford

During the past quarter, the Oxford Section activities for the current Institution year have been brought to a close.

The last meeting held was a film show given to members, only following the Annual General Meeting, and election of Officers for the coming year.

A further Committee Meeting was held in April to discuss and decide upon a theme and a programme for the Institution year 1958 - 1959. The Oxford Section Committee have decided upon a theme as follows: " The Effect of European Free Trade on British Industry". This theme has in turn been broken down

in a representative cross section of British industry under the following headings on which papers will be read:—

23rd September, at Banbury:
Under the heading of " MANUFACTURE OF POWER AND DISTRIBUTION EQUIPMENT FOR ELECTRICITY".

24th October, at the Brize Norton U.S. Airforce Base:
(Not yet confirmed). Under the heading of " OIL".

18th November, in the Oxford Town Hall:
Under the heading of " MOTOR CARS".

20th January, in the Oxford Town Hall:
Under the heading of " DOMESTIC ENGINEERING PRODUCTS".

17th February, in the Oxford Town Hall:
Under the heading of " MACHINE TOOLS".

17th March, at Aylesbury:
Under the heading of " CHEMICALS AND PLASTICS".

21st April, at Witney:
Under the heading of " ECONOMY SUMMARY".

The policy established over the last three or four years will continue to be followed, i.e., that the Institution of Production will carry their meetings to the whole of the Oxfordshire area.

The Oxford Section looks back to a successful year which has just passed to include a Presidential visit, with every confidence for a new year with what is hoped to be a topical theme embodied in some new Papers to be read to an audience spread over a very wide area.

Reading

A very successful Section Annual Dinner attended by over 90 members and guests was held and presided over by Mr. H. Richardson; the function was all-male and its informality was much enjoyed.

Mr. R. F. Newman, C.B.E., M.I.Prod.E., was the Guest of Honour, and among other guests was Mr. Woodford.

Entertainment was arranged by Mr. Mott and Mr. Waterhouse and this very largely contributed to the enjoyable and happy evening.

An inaugural lecture meeting was held at Newbury, as it was thought that this area should be tried out for support and interest. Much to the Section's gratification, there was an attendance of 75. The Committee have agreed unanimously that a regular lecture for Newbury must be included in the lecture programme.

SOUTH EASTERN REGION

Regional Report

The Committee of the South Eastern Region have now completed the assessment of the papers submitted for the Graduate Prize Competition which was instituted this year, and have decided to award a prize to Mr. H. S. Woodgate of the London Section for his Paper entitled, " Production Planning in a French Aircraft Manufacturing Organisation."

On 24th April, a Regional Meeting was held in London. At this meeting Professor Postan delivered a Paper entitled, " British Engineering since the War", to an audience of some 60 or 70 members, whose interest was shown by a lively discussion which followed.

London

Looking over the Session's programme, meetings with one or two exceptions were well attended, and Papers gave rise to vigorous discussions on a variety of subjects. The Session ended with a lecture at Brighton which proved to be most interesting.

The lecture programme for the coming Session is almost complete. with lectures on alloy steels, inspection, production of plastic mouldings, preventative maintenance and liberal studies already arranged. Further lectures are under discussion, and tentative enquiries have been made concerning a particular lecture for the 1959 - 1960 Session.

Since the last Section Quarterly Report was published, the Section Committee elections have taken place. Mr. G. A. J. Witton has been elected as Chairman of the London Section Committee, commencing his term of office in June of this year.

The retiring Chairman, Mr. G. R. Blakely, is thanked most sincerely for his services during the past two years.

London Graduate

At a meeting held on 9th May, 1958, the Committee discussed at length the figures provided at the Region and Section Hon. Secretaries' Conference concerning the publicising of lecture meetings. Opinion was divided on the abolition of lecture tickets, but it was felt that it may be worth while dispensing with tickets for members and substitute some form of personal contact by Committee Members.

The Committee agreed, however, that the sending of tickets to visitors purely as a form of notice was unnecessary. They felt that this could best be covered by sending the Regional programme under cover of a formal letter of invitation at the beginning of the lecture season.

It was unanimously agreed that the Regional programme booklets and the Journal Supplement were essential.

Luton

During the quarter under review, the Section Committee has considered at some length the means by which greater interest in Institution affairs may be fostered among members. It is felt that during the Summer months there is normally an absence of contact between members through the medium of the Institution, and therefore the Section is organising two social events, at which ladies will be welcome.

On 24th June, the Section visits the London Docks, and will be guests of the P. & O. Steamship Company.

Additionally, a Motor Treasure Hunt is projected for September, and for each of these events an encouraging response has been received. It is hoped that these are the forerunners of other social gatherings, which will give a wider meaning to Section activities than in the past.

The Section continues to have active co-operation with a representation on the local Management Association, and Productivity Committee.

SOUTH ESSEX

The Section Annual General Meeting was held at the Mid-Essex Technical College, Chelmsford, when 17 Corporate Members of the Section were present. This was followed by an open meeting, two films being shown.

The final meeting of the 1957 - 1958 Winter Session was held at Ilford, when 31 members and friends met to listen to Mr. P. H. Herbert, of Ilford Limited present a Paper on " Recent Developments in Industrial Photography."

The Section Committee are preparing the 1958-1959 programme, and are again arranging to hold meetings at Chelmsford, Ilford and Southend-on-Sea.

SOUTH WESTERN REGION

Cornwall

The Conference organised by the Section on the theme, " Improving Productivity by the Use of Compressed Air " was the climax of activity in the Section for 1957 - 1958.

It afforded Cornwall members in particular an opportunity of meeting the President of the Institution. Lord Halsbury addressed the assembly at the opening ceremony and took an active part in the discussions which followed later sessions.

The function was reasonably well attended and of the 150 delegates about 80 came from outside Cornwall. Like the first Conference held in 1955, the programme was of a high technical level. Five papers were presented by leading technologists in their particular field. The papers and discussions were supplemented by an excellent film programme showing the various advantages and aspects of air on production. A small display of air-operated equipment, adjacent to the Conference Hall, created much interest.

On the second day, a conducted tour of the new gigantic dock at Falmouth was much appreciated by about 80 of the delegates. The weather was unkind, but the visit afforded an invaluable experience to all concerned with the applications of air to production.

The Cornwall Section Committee would like to extend thanks to all concerned for the help and support so readily given which did much to make the Conference a success.

The co-operation and assistance of the Speakers, Chairman and Exhibitors is greatly appreciated.

The excellent manner in which the efforts were co-ordinated by Mr. Woodford, Mr. Caselton and Miss Freeman at Headquarters did much to make the Conference in Cornwall quite an occasion.

WALES REGION

Regional Report

A party of twenty-eight members and their ladies were the guests of Hoover (Washing Machines) Limited on Wednesday, 26th March, and enjoyed a most interesting and instructional tour of the works. Appreciation is expressed to Messrs. Hoover Limited, for their welcome and co-operation during this visit.

The Regional One-Day Conference took place on 29th April, 1958, at the premises of the B.P. Refinery (Llandarcy) Limited; 120 delegates took part, of whom 70 were Regional Members.

The subject for discussion, " What New Skills does the Future Demand " provided unlimited scope for the various groups. Mr. W. H. Bowman, Regional Chairman, introduced the President of the Institution, The Rt. Hon. The Earl of Halsbury, who opened the proceedings with an address covering the key points of the theme, after which the delegates formed into groups for discussion on their particular subject of interest.

Mr. R. B. Southall summed up the findings of each group, and the Conference was brought to an end by Mr. Abraham, Cardiff Section Chairman at 6.30 p.m.

The Conference was a grand success and the Region is deeply indebted to their hosts for the occasion, the BP Refinery (Llandarcy) Limited for the excellent facilities provided. The occasion was finally rounded off by the members of the Regional Committee entertaining the President and the Llandarcy hosts to dinner at the Seabank Hotel, Porthcawl.

Cardiff

The highlight of the Section's activities over the past quarter was undoubtedly the One-Day Conference held at the National Oil Refinery, Llandarcy. The Cardiff and Swansea Sections collaborated to make this one of the most successful events held in the area.

Elections for Section Chairman and Committee Members for the 1958 - 59 Session have been completed and consideration is being given to the lecture programme for the next Session. The last Session can be considered one of the most successful of recent years and the lecture programme attendances in particular have given the Committee considerable satisfaction. It is hoped to repeat this success in the next Session.

Swansea

The retirement from active duty of the Section Chairman and Regional Committee Member, Capt. V. J. Sankey, R.N. (Retd.), is recorded with regret. Capt. Sankey is leaving the district to enjoy a well-earned retirement on the South Coast.

The Section Committee are now preparing the Winter Programme of lectures, the election of and dealing with Regional and Section Officers for the coming year.

The Regional Conference was an outstanding success and members of both Cardiff and Swansea Section Committees can be justly proud of their effort in this filed, which augurs so well for the future of the Institution in South Wales.

SECTIONS OUTSIDE THE UNITED KINGDOM

Adelaide

The programme for 1958 will include six lectures, two visits and one film evening. The lectures will form a series and will follow a product through from market research and product design to sales and distribution. Speakers who are specialists in their particular field have been selected to give each of the papers.

At its May meeting the Committee regretfully accepted the resignation of Mr. W. L. Hemer from the office of Hon. Secretary and from the Committee. This action was necessary in the interests of Mr. Hemer's health.

So far this year there has been little progress made with the establishment of the P.E. diploma course at the Adelaide University due, largely, to changes in staff at the University.

Melbourne

The Melbourne Section's activities have been most successful over the last quarter. There have been three meetings and one works visit,

On May 12th, 86 members attended to hear a Paper entitled " Tracer Controlled Machining Operations," presented by Mr. C. E. Waller, B.Mech.E., Research Engineer, McPherson's Limited. Mr. Waller is a nephew of the noted research worker, Hans Ernest, and spent some years working under him at Cincinnati, U.S.A.

On April 9th there was a joint meeting with the Institute of British Foundrymen's Australian Branch. Two papers were presented on " Shell Moulding Suits Production Engineers," by Mr. G. P. Adams, Managing Director, Shellmould Pty. Ltd., and Mr. R. B. Whitelaw, Chief Metallurgist, Russell Manufacturing Co. Pty. Ltd.; 110 members of the two Institutions attended this meeting.

There was a combined meeting on May 14th with the Graduate Section. This was a question night, with six questions pertaining to Productivity submitted by the Graduates. These questions were answered by a panel from our Productivity Work Group; 67 members attended this meeting.

As an experiment, a special meeting was held during March to hear a talk by Mr. Paul Campbell-Tiech on his recent visit to the Continent. This meeting was in addition to the regular monthly meeting, and was an informal night, taking the form of a Buffet Dinner in a private room at the University of Melbourne. Mr. Campbell-Tiech spoke after dinner, his subject being " Present Technical Trends in Europe and Economic Business Influences." The meeting was highly successful, with an attendance of 50.

The first works visit for the year was held on May 16th to General Motors-Holdens Frigidaire Division and Body Assembly Plant, Dandenoing. This factory is the most modern, and the largest, automotive factory in Australia. Added interest was a tour through the new Frigidaire Division. Forty members attended and were most impressed with the factory layout, mechanical handling and large range of machine tools. Members were the guests of General Motors to luncheon.

Melbourne Graduate

(*i*) *Works Visit to General Motors-Holden's Ltd.*

This visit to the modern mechanised foundry of G.M.H. proved very successful. The tour of the foundry was most interesting and the excellent supper arrangements made by the Company afforded those present the opportunity to enjoy a memorable social evening.

(*ii*) *Lecture by Mr. I. Pitman—" The Latest Trends in Plastics."*

Mr. Pitman's lecture covered the various types of plastic materials in common use and their applications, with the aid of many fine samples of plastics products. The latest forming methods and processes were then described and finally Mr. Pitman gave his impressions of the future field for plastics.

The Section was very pleased to welcome a number of Senior Section Members who attended.

(*iii*) *Question Night with Melbourne Senior Section*

Six questions submitted by Graduates and Students, and relating to " Productivity " were put before a panel comprising Members of the Melbourne Section Productivity Group. The questions were very ably answered by the panel and the agenda allowed time for discussion and further questions.

Sydney

The increase in the numbers attending monthly lecture meetings, reported after the March meeting, has been evident all this year.

In April, Mr. W. Bernard spoke on " New Automatic Welding Processes and Electrodes for Automation "; followed in May by Mr. N. G. Fraser who took as his subject " Deep Drawing Sheet Steel—its Manufacture and Properties."

For the June Meeting, Mr. C. L. Pyman, A.M.I.Prod.E., read a paper entitled " The Scope for Cost Reduction through Production Engineers."

Arrangements are well in hand for the visit to the Snowy Mountains Scheme planned for October.

Production Engineering Research Association of Great Britain

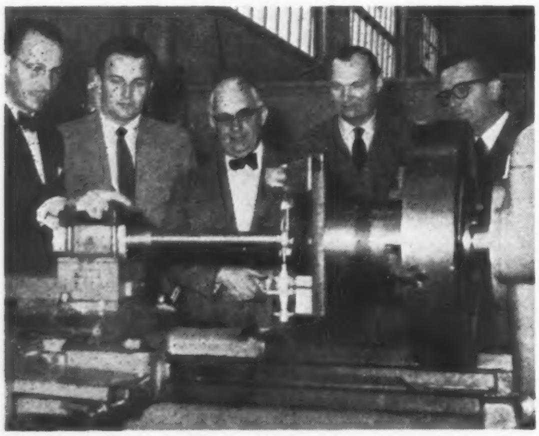
PERA Quarterly Newsletter to the Institution

official inauguration of new workshops and laboratories

On Tuesday, 3rd June, The Rt. Hon. Viscount Chandos, P.C., D.S.O., M.C., officially inaugurated PERA's new workshops and laboratories at Melton Mowbray. The ceremony was attended by about 150 distinguished guests and representatives of member firms, and was widely publicised on television and radio, and in the press.

During his inauguration speech Lord Chandos pointed out that "there are few connected with industry who do not know how massive can be the savings by improved methods of production. I know of one company which, by using improved techniques developed by PERA, has saved about £40,000 a year in the production of one component and I could multiply this instance many times from my own experience.

"You must not regard the opening of this building as the climax of the Association's development. It is one step along a broad highway to the future which we are now taking. The whole present membership of the Association would hardly cover 10% of the potential membership of the British engineering industry. We must aim, and I know that we will succeed, at bringing into this co-operative effort, more and more firms.



Dr. D. F. Galloway (left), Director of PERA, describing developments in PERA's vibration researches to Professor Kaczmarek (second from left), Mr. G. R. Pryor, Vice-President of The Institution of Production Engineers (centre), Mr. W. F. S. Woodford (second from right), Secretary of the Institution, and Mr. Jabkiewicz (right). Professor Kaczmarek and Mr. Jabkiewicz were members of the party of Polish scientists and engineers who visited the Association recently.

"Quite apart from the competition which there is today from the United States, with its huge industrial installations, it may not be long before Russia will wish to enter the export markets and, finally, as we all know in our daily lives, Germany and Japan, who were knocked out as competitors in many fields by the War, are now lively competitors, and their production mostly comes from plants which have been built since the War. This in particular represents a threat or challenge to our industry. That we can meet it, and outdo and outface this competition, is my firm belief but we shall only do it by attaching the proper importance to schemes for improving our production techniques, lowering our costs, reducing the labour content of many of our products, and reducing the manual effort and fatigue of those who work at these tasks.

"In this, PERA plays a vital part and deserves wide support from the engineering industry. It is, therefore, with pleasure that I declare the new research building open, and I express the hope that it will contribute to the prosperity and to the proud future of British industry."

Before inviting Lord Chandos to declare the building open, Sir Lionel Kearns, Chairman of Council, who presided at the ceremony, asked Mr. A. L. Stuchbery, Chairman of the Technical Policy Committee and of the Buildings Panel, to outline the steps which had led to the construction of the building. Mr. Stuchbery explained that for many years, the Association's researches had been carried out in converted stables, and with the continuous growth in membership it became clear some years ago that a large new research block was essential to house the Association's research facilities and staff. An approach was made to the Department of Scientific and Industrial Research, who generously agreed to make a capital grant of £100,000 provided a similar sum of money could be raised from industry. A large number of member firms subsequently subscribed substantial sums of money to the building fund and Mr. Stuchbery, on behalf of the Association, thanked the D.S.I.R. and members for the very generous support which had made possible this vitally important addition to the Association's facilities for helping member firms.

visit from Polish engineers

On Friday, 30th May, a party of Polish scientists and engineers, whose visit to the United Kingdom was arranged by The Institution of Production Engineers, spent the day at PERA and studied the progress being made in the various researches being carried out in the new workshops and laboratories. The party was accompanied by Mr. G. R. Pryor, a Vice-President of the Institution, and Mr. W. F. S. Woodford, Secretary of the Institution.

news of members

Mr. C. Ellis, Member, who is Director of Production at Edward Pryor & Son Ltd., of Sheffield, is visiting Canada and America for a four-week period to increase dollar export sales to those countries.

Mr. C. R. English, Member, formerly Staff Inspector for Engineering, Ministry of Education, was recently appointed Chief Inspector for Further Education (Industry and Commerce).

Mr. B. G. L. Jackman, Member of Council, who joined Lockheed Hydraulic Brake Co. Ltd. in 1956, as General Manager of the Brake Division, has been appointed an Executive Director of the Company. He was formerly with The Rover Co. Ltd., followed by a period as Works Director of The British Heat Resisting Glass Co. Ltd., at Bilston, Staffordshire.

Mr. Jackman was Chairman of the Birmingham Section of the Institution from 1954 - 1956, and recently relinquished office as Midlands Regional Chairman. He is Chairman of the Research Committee, a member of the Awards Sub-Committee, and has served on the Finance and General Purposes Committee and the Education Committee.

Mr. N. A. Esserman, Member, was recently appointed Director of The National Standards Laboratory, C.S.I.R.O., New South Wales.

Mr. C. J. Luby, Member, was recently appointed Managing Director of Rotol Ltd. and British Messier Ltd., where he has been Assistant Managing Director since 1956. Mr. Luby serves on the Western Section Committee.

Mr. D. H. Mason, Member, has now taken up an appointment as Regional Officer for the London Area of the British Productivity Council.

Mr. Matthew Seaman, Member, a Director of British Oxygen Gases Ltd. and General Manager of the Equipment Division, has been elected to the Board of Governors of Mount Grace School. Mr. Seaman is a Past Chairman of the Institution's Editorial Committee and has served on the Conference Organising Committees and on the Research Committee.

Mr. R. O. Birch, Associate Member, has relinquished his Directorship of B. & D. Tool Co. Ltd., and has now taken up a Senior Executive position with Alan Keir Ltd., London.

Mr. C. A. I. Blackwell, Associate Member, has recently taken up an appointment as Mechanical Engineer in the City Engineer's Department, Bulawayo, Southern Rhodesia.

Mr. George Butler, Associate Member, has been appointed to the Board of Directors of The Butler Machine Tool Co. Ltd., Halifax, which he joined as an apprentice 29 years ago. Mr. Butler (who is not related to the family controlling the business) started work in the drawing office and last January became Chief Designer.

Colonel H. Cliff, Associate Member, has recently retired from the Service and has taken up the appointment of Work Study Officer at Charing Cross Hospital.

Mr. Frank Clymer, Associate Member, has been appointed Technical Director of F. H. Lloyd & Co. Ltd., and also Technical Director of Lloyds (Burton) Ltd.

Mr. R. Gabriel, Associate Member, has been appointed Managing Director of Charles Churchill & Co. Ltd., the parent Company of the Charles Churchill Group.

Mr. G. B. Hart, Associate Member, has now completed his period of duty in Ghana as Chief Engineer to Bibiani (1927) Ltd. and Ashanti Goldfields Corporation Ltd., and has returned to the London office of these Companies to take up the appointment of Consulting Mechanical Engineer.

Mr. N. Jackson, Associate Member, has recently been appointed as Lecturer at the Sheffield College of Commerce and Technology.

Mr. D. J. I. Gray, Associate Member, joined W. E. Norton (Machine Tools) Ltd. as Technical Sales Manager on 1st July, 1958, at the same time relinquishing the position of Manager, the Compressor Division of the Cooper-Stewart Engineering Co. Ltd., a position to which he was appointed on 1st January, 1957. Mr. Gray was previously the Works Manager of that Company.

Mr. W. F. Marshall, Associate Member, has relinquished his appointment with The Rover Co. Ltd., Solihull, and has taken up an appointment as Production Control Manager at Marshall, Sons, & Co. Ltd., Gainsborough.

Mr. Moresly Reay, Associate Member, has recently returned from Canada to take up an appointment as Production Engineer with The Wellman Smith Owen Engineering Corporation Ltd., Falls Foundry, Belfast.

Mr. H. W. Rhodes, Associate Member, has now taken up a position with Wm. Doxford & Sons (Engineers) Ltd., Sunderland.

Mr. J. Cartwright, Graduate, is now a Grade " B " Assistant Lecturer at Enfield Technical College.

Mr. S. B. Gupta, Graduate, has been appointed as a Works Engineer, Colombo Plan Expert, Kangaroo Tractor Station, Anuradhapura, Ceylon, since February, 1958.

Mr. R. Stone, Graduate, has recently been appointed Contract Manager with Orenda Industrial Inc., a member of the Hawker-Siddeley Group.

obituary

Mr. Leonard Austin, Member, who until his resignation last June, was Managing Director of Wadkin Ltd., Leicester. Mr. Austin joined the Company as Works Manager in 1920, was appointed a Director in 1936, and Joint Managing Director, with the late Sir Holland Goddard, in 1948. He became Managing Director in 1956, when Sir Holland relinquished executive office.

Mr. Austin was a Past Chairman of the Leicester Section of the Institution, where he will be warmly remembered for the considerable contribution he made towards furthering the work of the Institution.

Hazleton Memorial Library

REVIEW & ADDITIONS

" Oxford History of Technology." Volume III. *Oxford, Clarendon Press,* 1957. 766 *pages. Plates. Illustrated. Diagrams.* £8 8s. 0d.

This volume covers the 250 years between 1500 and 1750 A.D., that is, the immediate pre-Industrial Revolution period. Anyone wishing to gain further knowledge concerning the industrial and social pressures that led to the Industrial Revolution would be well advised to spend some time reading this work, if not in detail, at least with sufficient attention to absorb a representative selection of the wide range of crafts presented.

The work covers technology in an all-embracing manner, dealing as it does with everything from food and drink to precision instruments. There is something to be gleaned by the students of many professions; the general engineer will find a great deal of fascinating information in most of the Parts, while Parts II and V are of particular interest to production engineers, since they deal with " manufacture " and " approach to science ". Part III, which is entitled " Material Civilisation ", will be most interesting to the architect concerned with building, construction and town planning. Part V will provide much information to the individual engaged in the instrument field and the section on " Mechanical Timekeepers " is very well presented, illustrating the very high standard of mechanical manufacture and science reached at an early date.

The layout of the work is excellent, the print being easy to read and the many subdivisions employed making it an easy book to refer to. In this respect there is a very useful index. The standard and multiplicity of pictures and diagrams used to illustrate the text help to make it a delightful volume to dip into.

This is a fascinating work, either to refer to occasionally or to study carefully, and one person at least is eagerly awaiting the publication of the fourth volume covering the Industrial Revolution.

The price of the volume is eight guineas, and it is, therefore, unlikely to find its way into many private collections. This is a great pity, but for a work of such scholarship the price is justifiable. This volume will be a valuable addition to the shelves of libraries and institutions.

J.I.

Canada. National Research Council — Technical Information Service. **"Heat Economy in Textile Plants."** Notes with annotated bibliography. Compiled by F. G. Green. *Ottawa, the Council, April,* 1958. 16 *pages. Mimeo.* (T.I.S. Report No. 56.)

Garside, James E. **"Process and Physical Metallurgy."** 2nd edition. *London, Griffin,* 1957. 593 *pages. Illustrated. Diagrams.* 54s.

This book is written principally for the engineer user of metals and alloys. The subjects dealt with are: ore dressing; refractory materials; fuels and furnaces; fluxes and slags; casting; deformation pyrometry; metallographical microscopy; the constitution of alloys; the metallic state; physical changes in metals and alloys caused by deformation and annealing; the joining of metals and alloys; powder metallurgy; metallic corrosion; the structure and treatment of specific ferrous and non-ferrous metals and alloys.

Green, W. G. **"Theory of Machines."** *London and Glasgow, Blackie,* 1955. 1,034 *pages. Diagrams.* 45s.

The main purpose of this book is to meet the needs of students preparing for the external degree examinations of the University of London, the National Certificate examinations; and for the examinations of professional institutions. The first two chapters are devoted to the study of "Dynamics of a particle and of a rigid body", since, in the author's experience, students often lack knowledge of the fundamental approach to this subject. Other chapters deal with the kinematics of machines and geometric representation of motion; the kinematics of machines — mechanisms with lower pairs; the kinematics of machines — graphical analysis; the direct acting engine mechanism; the balancing of machines; governors; valves and valve gear; friction; lubrication and efficiency of machines; film lubrication; belt friction; brakes and dynamometers and the motion of vehicles; higher pairing; toothed gearing; cams and cam motions; the vibrations of mechanical systems; motion in three dimensions. The worked examples throughout the book are taken for the most part from the examinations of London University and of professional institutions.

Heiland, Robert E., and Richardson, Wallace J. **"Work Sampling."** *New York, London, etc., McGraw-Hill,* 1957. 234 *pages. Diagrams. Charts. Tables.* 46s. 6d.

The term "work sampling" was probably invented in America, although the technique was first used in this country. The statistician Tippett used it when he applied statistical sampling to the problems of loom breakdowns in a textile mill. It is defined by the authors of this book as "a measurement technique for the quantitative analysis in terms of activity of men, machines or any observable state or condition of operation". In a preliminary chapter they amplify this definition. This chapter is followed by ones giving examples of the use of the technique, on its basic theory, on work sampling routine. The mathematical bases on the technique (e.g., the binomial theorum) are dealt with in three chapters, and these are followed by chapters on presenting the results of work sampling, and on "selling" work sampling to others. Eight case studies are presented (including one on materials handling and one on machine shop incentive allowances).

Heimer, Robert C. **"Management for Engineers."** *New York, London, etc., McGraw-Hill,* 1958. 453 *pages. Diagrams.* 52s. 6d.

Deals with legal, financial labour and other non-engineering aspects of industrial management. It is specifically written for engineers who need to be acquainted with the day-to-day workings of their firms, both as economic institutions and as "co-ordinate organisations made up of individual participants".

Jones, E. J. H. **"Production Engineering: Jig and Tool Design."** 6th edition. *London, Newnes,* 1956. 355 *pages. Illustrated. Diagrams.* 30s.

A comprehensive textbook of jig and tool design, which includes a chapter on the organisation of a jig and tool department. Two new chapters (on transfer machining and on deep-hole boring) have been included in this edition.

Kendall, Maurice, and Buckland, William R. **"A Dictionary of Statistical Terms."** *Edinburgh and London, Oliver and Boyd for the International Statistical Institute,* 1957. 493 *pages.* 25s.

Prepared with the assistance of the United Nations Educational Scientific and Cultural Organisation. Pages 1 - 319 give full definitions of English statistical terms, and pages 321 - 493 comprise French-English, German-English, Italian-English and Spanish-English glossaries.

Karga, Delmar W., and Bayha, Franklin H. **"Engineering Work Measurement."** The principles, data and techniques of methods-time measurement, modern time and motion study and related applications engineering data. *New York, Industrial Press,* 1957. 635 *pages. Diagrams. Charts.* Official MTM Data card in pocket.

A textbook of time and motion study with special reference to the MTM system. The approach to the subject is practical. Problems are given at the end of each chapter.

King, Geoffrey, and Butler, C. T. **"Principles of Engineering Inspection."** *London, Cleaver-Hume Press,* 1957. 264 *pages. Illustrated. Diagrams.* 25s.

Contents: The organisation of inspection — The inspection of metallic raw materials — Inspection of non-metallic raw materials — Metallurgical examination — Inspection of primary production — Heat Treatment — Anti-corrosion coatings — Interpretation of drawings — Inspection of machined components — Inspection of surface finish — Design and manufacture of gauges — Critical examination of machined components — The time element — The statistical control of quality — Setting up an inspection system.

Linder, L. **"Safe Working Loads for Lifting Tackle."** 2nd edition. *London, Coubro and Scrutton Ltd., Testing Department,* 1952. 344 *pages. Diagrams. Tables. Charts.* 45s.

Notes and tables for the estimation of safe working loads. All the data is brought into line with the latest British Standards for lifting tackle.

McCormick, Ernest J **"Human Engineering."** *New York, London, etc., McGraw-Hill,* 1957. 466 *pages. Illustrated. Diagrams.* 64s.

The author is Professor of Psychology, Occupational Research Centre, at Purdue University. He defines human engineering as the "adaptation of human tasks and working environment to the sensory, perceptual, mental, physical, and other attributes of people". The author is not satisfied with the term "human engineering", but uses it in preference to other terms such as "ergonomics" or "biomechanics".

Contents: Introduction — Light and seeing — Illumination — Visual displays — Colour — Sound and hearing — Auditory communications — Noise and its effects — Atmospheric conditions — Body orientation and acceleration forces — Human motor activities: speed and accuracy — Human motor activities: strength and force — Space requirements — Design and arrangement of controls and displays — Arrangement of equipment — Human beings in relation to equipment.

Parker, S. **"Drawing and Dimensions."** *London, Pitman,* 1956. 306 *pages. Diagrams.* 35s.
This book was written to explain fully the principles of geometry upon which the dimensioning and tolerancing methods outlined in British Standard 308 (Engineering Drawing Practice) are based.

Parsons, C. W. S. **"Estimating Machining Costs."** *New York, London, etc., McGraw-Hill,* 1957. 366 *pages. Diagrams.* 62s.

The object of this book is to enable the engineer "to study the engineering drawing of a workpiece and decide how it can be made, to make a breakdown analysis of the necessary operations, considering men, materials, tooling and machines, and to put time and money values on the various factors contributing to the completion of the work". Part 1 describes the information needed for cost estimating (e.g., about materials, tool life, materials handling), and describes the techniques of cost estimating. Part 2 is devoted to cost estimating applications as related to basic types of machine tools (e.g., milling machines, turret lathes, drilling machines).

Steeds, W. **"Engineering Materials Machine Tools and Processes."** 3rd edition. *London, etc., Longmans,* 1957. 426 *pages. Illustrated. Diagrams.* 35s.

This book is designed to give the student engineer a knowledge of the basic branches of mechanical engineering other than design. This edition is considerably enlarged and includes information on air gauging, transfer machines, contour copying and tape control of machine tools.

Contents: Testing and inspection of engineering materials — Ferrous materials — Non-ferrous alloys — The production of castings — Forging — Press tool work and spinning—Fabrication by welding—Plastic moulding — Classification of machine tools — The lathe — Tool life — The capstan and turret lathes — The machining of holes — Jigs and fixtures — The milling process — Planing, shaping and slotting machines — Broaching — Gear cutting — The grinding process — Honing, superfinishing and lapping — Measuring methods and gauging — Transfer machines and automation.

Wolfe, John H., and Phelps, Everett R. **"Practical Shop Mathematics."** 3rd edition. 2 volumes. *New York, London, etc., McGraw-Hill,* 1948 *and* 1949. Vol. 1, Elementary, 370 pages. Vol. 2, Advanced, 356 pages. 35s. 6d. each.

Walker, Charles R. **"Toward the Automatic Factory."** A case study of men and machines. *New Haven, Conn., Yale University Press; London, Oxford University Press,* 1957. 232 *pages. Illustrated. Diagrams.* 30s.

This book presents the results of a study undertaken on behalf of the Institute of Human Relations of Yale University. It is a sociological study of the effects of introducing semi-automatic machinery into an American steel mill (the Lorrain works of the National Tube Division of the United States Steel Corporation). It can be compared with a similar study undertaken in this country by Liverpool University's Department of Social Science of the relations between technical change and the social structure of a large steel works. (*Technical Change and Human Relations.* Scott, Banks, Halsey and Lupton. Liverpool University Press, 1956. Noted in the Journal, January, 1958.)

West, John C. **"Textbook of Servomechanisms."** *London, English Universities Press,* 1953. *Reprinted* 1955. 238 *pages. Illustrated. Diagrams.* 25s.

"An elementary textbook for scientists and technologists in the field of physics, mechanical, electrical and production engineering. The text, which is presented in an elementary manner, describes the scope and principles of automatic control and the techniques of design which are used in these systems. Each new idea is introduced by a simple example, the behaviour of which is explained on physical grounds and is accompanied by a mathematical analysis."

A supplement to the Hazleton Memorial Library Catalogue is available *gratis* from the Librarian.

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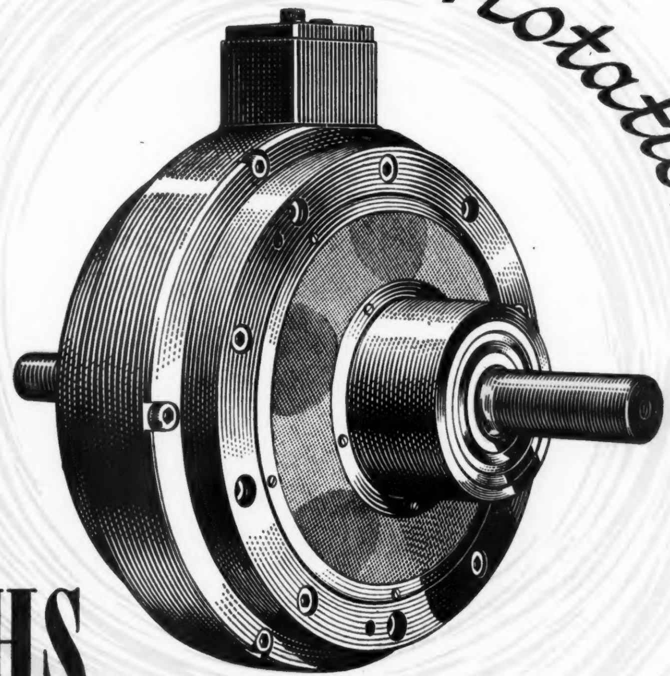

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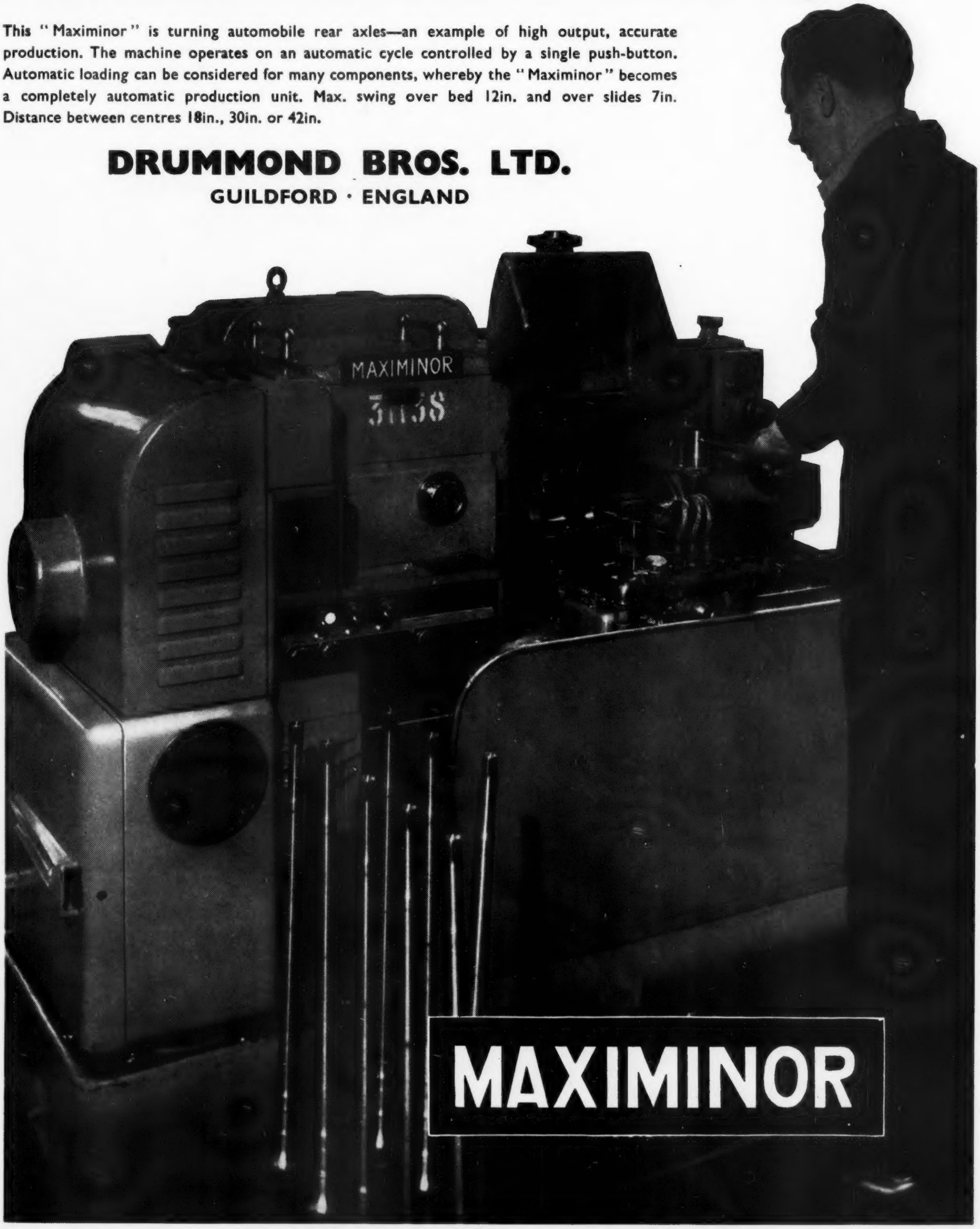

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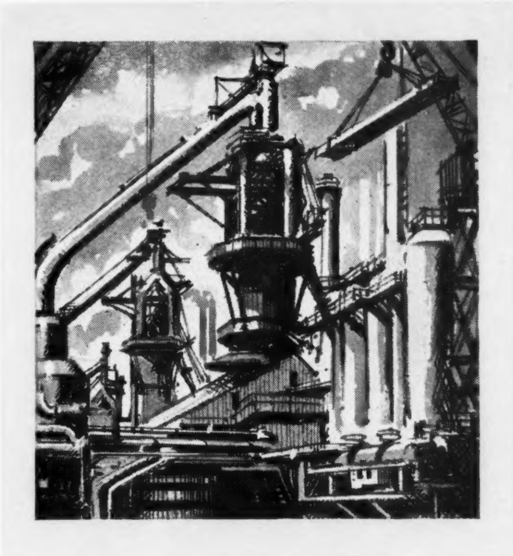

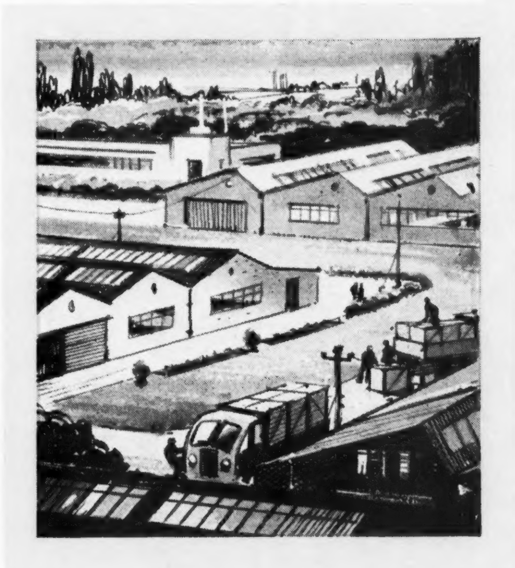

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TYPICAL PROFILING
FLOOR TO FLOOR TIMES
model J 6
Unitrace Profiling
Lathe
16·06" (9 min)
2·5"
(13 min)
24·625" (19 min)
LANG
PROFILING
TURNING
BORING
SURFACING
+
STANDARD SLIDING
SURFACING & SCREWCUTTING
LATHE ALL IN ONE MACHINE
43·25" (73 min)
LONDON OFFICE
ASSOCIATED BRITISH MACHINE
TOOL MAKERS LIMITED
17 GROSVENOR GARDENS SW1
ASSOC. BRITISH MACHINE TOOL MAKERS LTD
JOHN LANG & SONS LTD.
JOHNSTONE RENFREWSHIRE SCOTLAND
Telephone: Johnstone 400
Telegrams: "Lang Johnstone"

L217E1

Churchill

HBM

AUTOMATIC SIZING
INTERNAL GRINDING MACHINE

CHURCHILL Automatic Sizing Internal Grinding Machines are renowned for their accuracy and speed of production. The extensive experience gained from supplying very many machines has been fully utilised in the Model 'HBM' to ensure highly efficient operation over a wide range of work.

Single or double automatic cycle operation according to work.
Plunge cut and traverse grinding.
Feed accelerator reduces production time.
Exceptionally wide range of roughing and finishing feeds.
Diminishing rate of feed to zero with variable electric dwell at size position.
Adjustable oscillation for building-up finish on blind end and open short length bores.
Hand feed to dead stop for plain internal grinding.
Operational safety — provision for immediate interruption of automatic cycle for emergency run-out — enclosing of dogs and plungers eliminates "finger traps".
Can be equipped for combined hole and face grinding.

THE CHURCHILL MACHINE TOOL CO. LTD., BROADHEATH, nr. MANCHESTER.
Telephone : Altrincham 3262. Telegrams : Churchale, Manchester.
Export Sales Organisation : Associated British Machine Tool Makers Ltd., London, Branches and Agents.
Home Selling Agents : Charles Churchill & Co. Ltd., Birmingham and Branches.

PRECISION *plus* PRODUCTION

C661-ID


Butler
26" SUPER SHAPER
BUTLER
THE BUTLER MACHINE TOOL Co LTD HALIFAX ENGLAND
Economical · Sturdy
Flexible in Toolroom
or Production Shop
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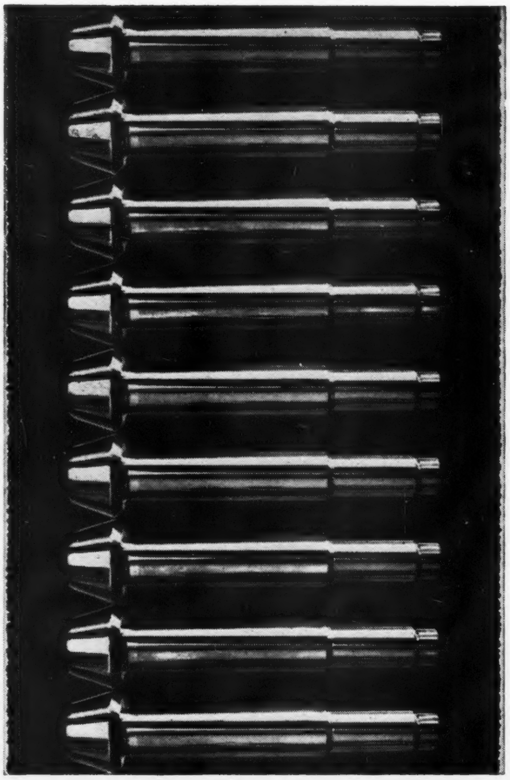
HALIFAX ENGLAND
TELEPHONE 61641
MAKERS OF PRECISION
PLANERS
SHAPERS
SLOTTERS

B 301 A



+GF+ Fully automatic Copying Lathes

Automatic programme:

- **Loading and unloading**
- **Spindle actuation**
- **Multi-cut cycle**
- **Automatic diameter control**

Setting up and changeover remains quick and easy.

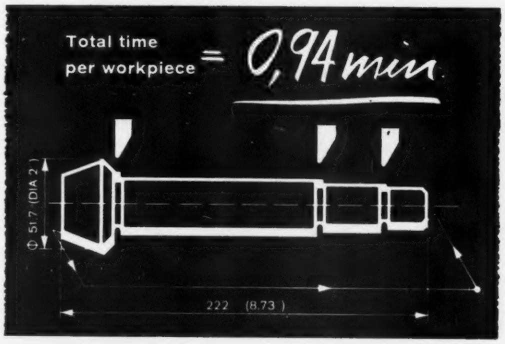
The programme may be cut into at any time.

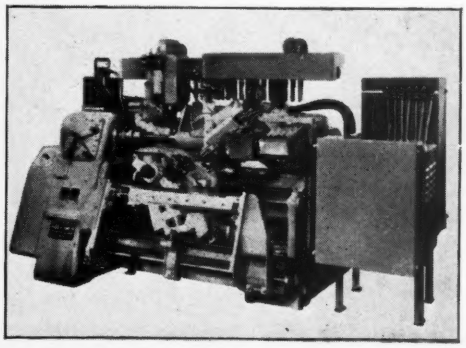
No rejects.

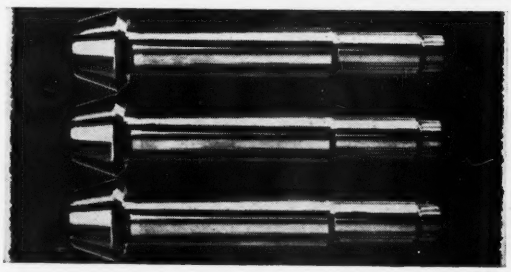
Two or more machines may be coupled together to form a fully automatic group.

One man can attend to several machines or groups of machines.

Every motion may be preselected individually, thus also permitting operation of the machine by hand.







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VAUGHAN ASSOCIATES LIMITED

4 QUEEN STREET, CURZON STREET, LONDON, W.1. Telephone: GROsvenor 8362-5

Midland Office & Demonstration Room
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Telephone: NOTTINGHAM 88008

NRP 2154

More wear resisting than Tungsten Carbide

MANUFACTURERS OF COMMERCIAL AND PASSENGER VEHICLES AND ENGINES

CONTRACTORS TO THE ADMIRALTY

PIONEERS OF THE Foden STEAM WAGON

FODENS
ELWORTH WORKS

Foden

LIMITED
SANDBACH CHESHIRE

TWO STROKE MARINE ENGINE

2nd May, 1957

YOUR REF ADPT/CAM.
OUR REF EJP/PB/LAB.

Messrs. Glostics Ltd.,
Tuffley Crescent,
Gloucester.

For the attention of Mr. A.D.P. Tallents.

Dear Sirs,

In January 1955 you supplied us with two shot blast nozzles in Carbon Tetra Boride. These were immediately put into use in the shot blast cabinets in our Heat Treatment department, working at an air pressure of 40 to 60 lbs/sq. in., and using 30 mesh angular chilled cast iron grit as the abrasive.

It is estimated that each nozzle has now been in service for more than 5,000 hours, and recent dimensional checks show the amount of wear to be almost negligible. We are advised by you that the original nozzle bore diameter was $\frac{3}{8}$", and it will be seen from the following figures that little, if any, wear has taken place.

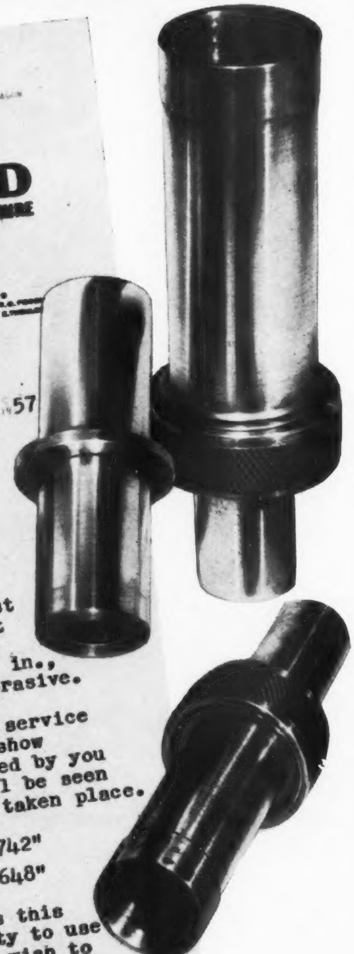
Bore Size at Throat of Nozzle	.3745" to .3742"
Bore Size 1" from Throat	.3650" to .3648"

We feel that an outstanding performance such as this should not go unnoticed, and you are therefore at liberty to use the information contained in this letter in any way you wish to further the publicising of C.T.B. nozzles.

Yours faithfully,
for FODENS LIMITED.

E.J. Phipps

E.J. PHIPPS,
CHIEF METALLURGIST.

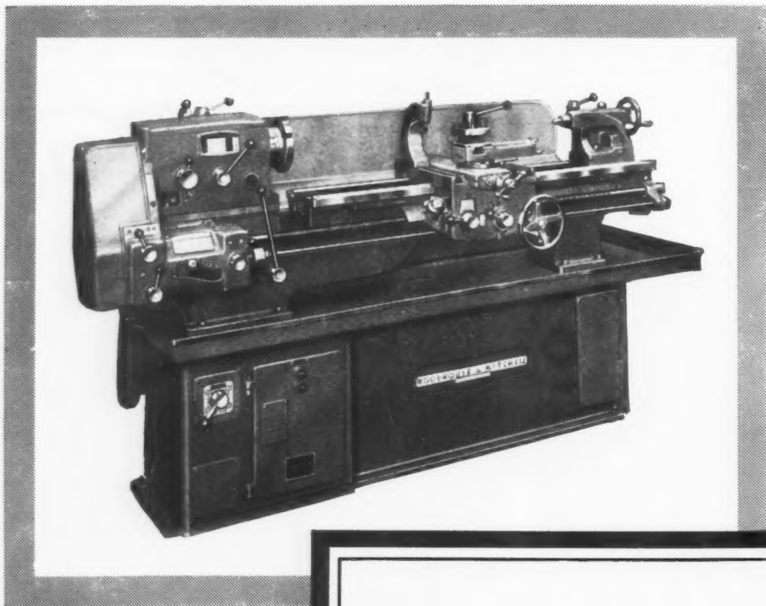


C.T.B SHOT BLAST NOZZLES

Glostics Ltd

AGENTS : IMPREGNATED DIAMOND PRODUCTS LTD : TUFFLEY CRESCENT : GLOUCESTER

WM LATHES

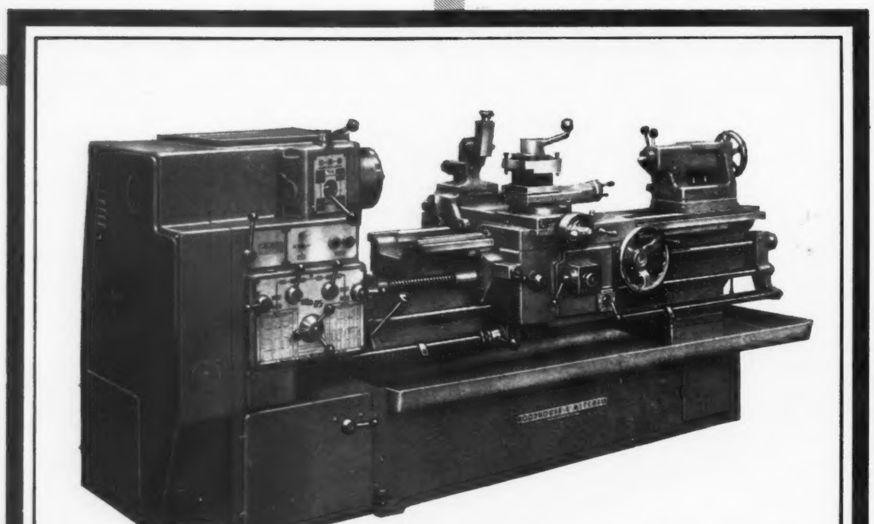


MODEL '70' JUNIOR 7" CENTRE LATHE

2 H.P. motor, 8 speeds, 30-437 r.p.m. also alternatives 44-640 r.p.m. and (when fitted with 2-speed motor) 30-874 r.p.m. Sizes to admit 45", 54" and 72" between centres. The Cabinet base illustrated is an optional extra.

*

MODEL '85' 8½" CENTRE LATHE



10 H.P. motor, 12 spindle speeds 21-945 r.p.m. Ideal for fast production, and tool-room work. Also made in 10½" size.

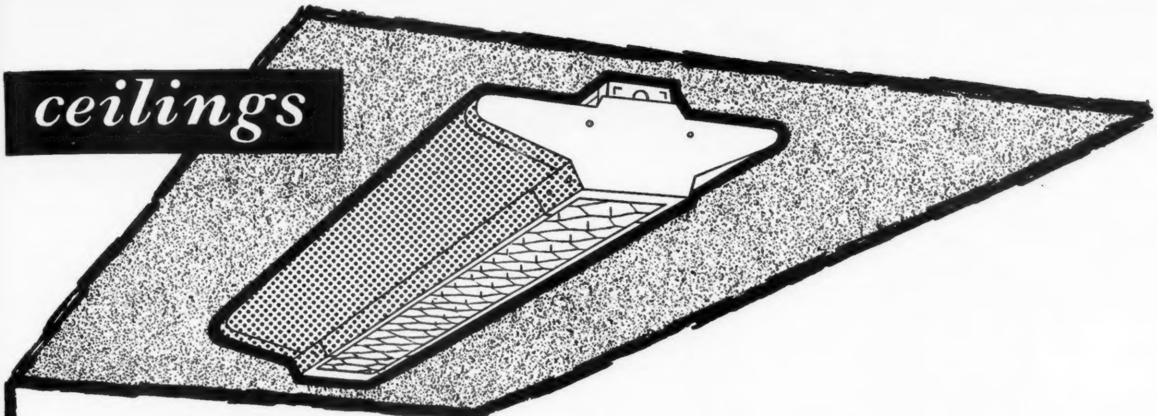
WOODHOUSE & MITCHELL

WAKEFIELD ROAD · BRIGHOUSE · YORKS

TELEPHONE: BRIGHOUSE 627 (3 LINES) TELEGRAMS: 'WOODHOUSE, BRIGHOUSE'

WM20

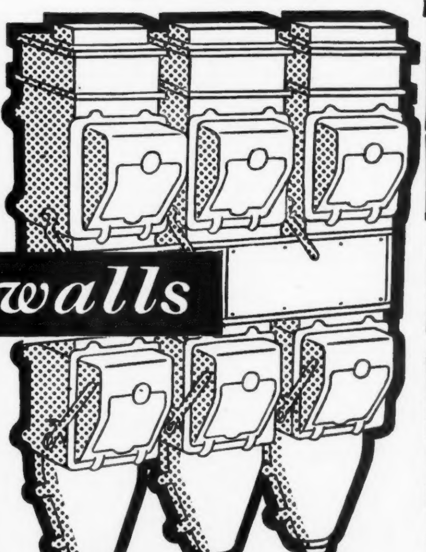
ceilings



RAWLBOLTS

For heavy fixing to Ceilings, Walls & Floors

walls



Rawlbolt fixings in concrete, whether in ceilings, walls or floors, are fast and efficient and make real savings in time and money.

Older methods of fixing involve laborious chiselling of holes, grouting in and waiting several days for cement to harden. With Rawlbolts, the job is far simpler and quicker. Drill a hole, insert a Rawlbolt and tighten up. Your equipment is fixed and ready for use immediately.

Civil Engineers, Consulting Engineers, Building Contractors, Structural Engineers are large and regular users of Rawlbolts.

TWO TYPES OF RAWLBOLT

LOOSE BOLT TYPE for fixing to floors

BOLT PROJECTING for fixing to walls and ceilings

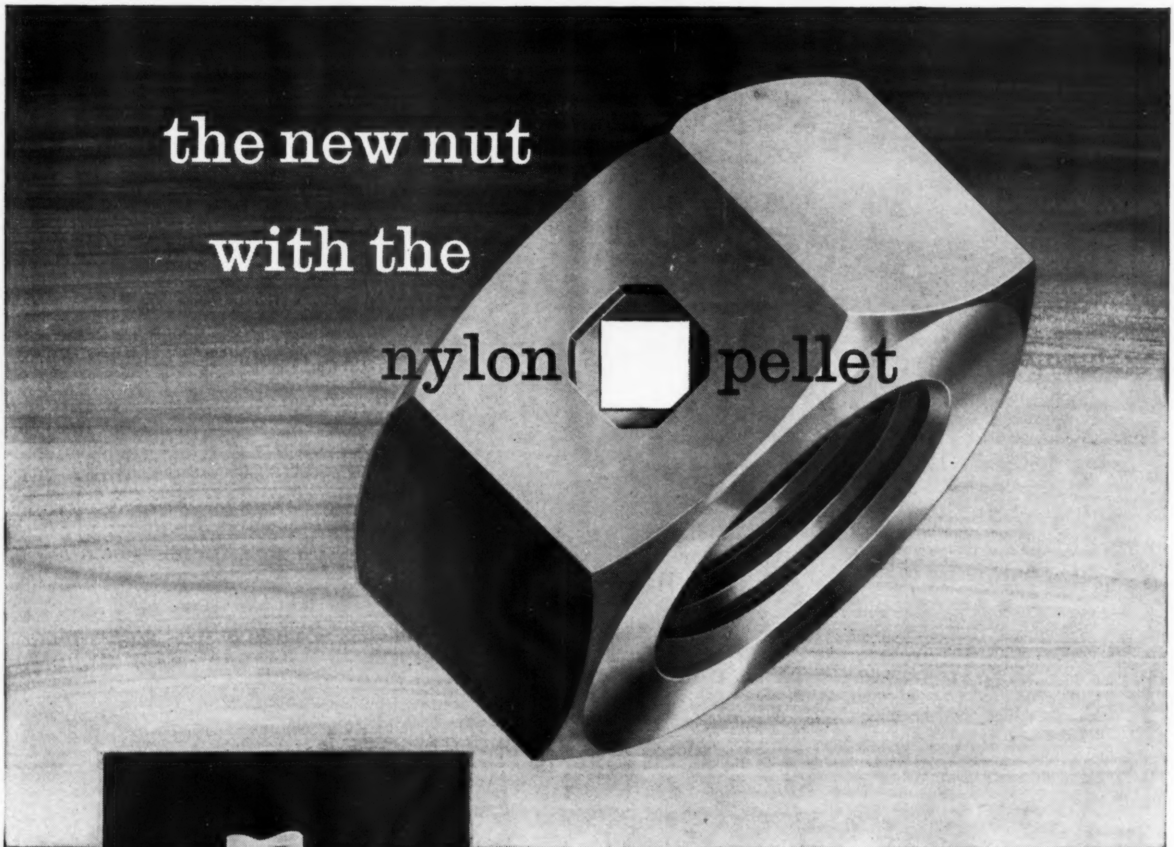
For more information, please write for Dimensional Chart of the Rawlbolt Range and full descriptive literature.

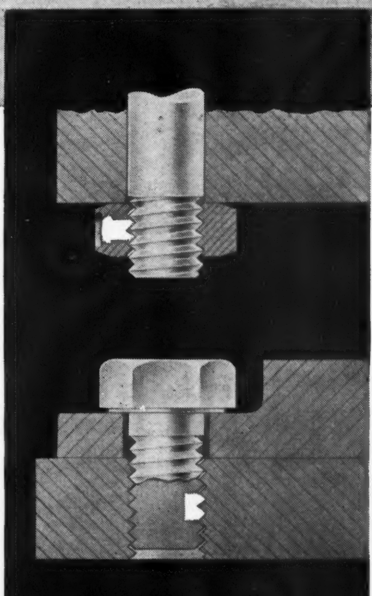
floors

THE RAWLPLUG COMPANY LTD., CROMWELL ROAD, LONDON, S.W.7.

B568 A

WEDGLOK





Wedglok nuts are completely self-locking. They will not work loose through vibration or reversal of stress. They need no locking devices—and the locking-action is unaffected by age or temperatures within the normal range.

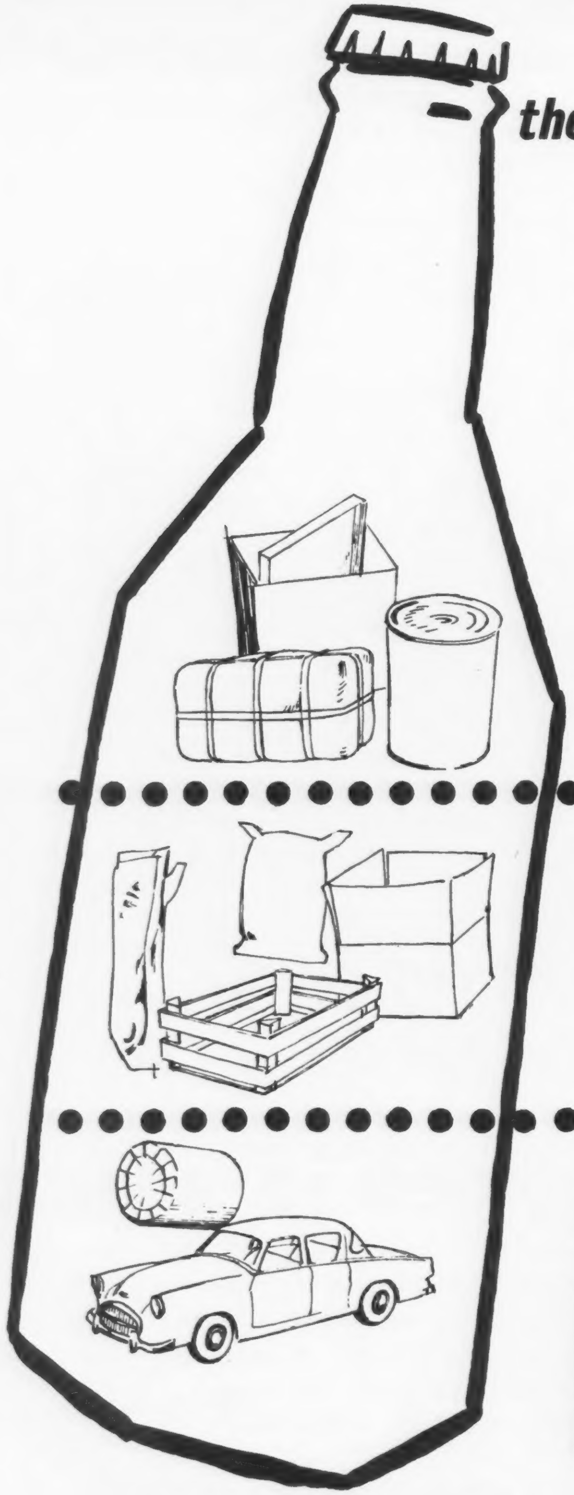
How is it done?

In a Wedglok nut the locking element consists of a tough, resilient nylon pellet. This is inserted in the body of the nut and projects slightly above the crest of the thread. When the nut is turned the pellet sets up a wedging action, gripping the threads tightly. This counter-thrust creates metal to metal engagement of mating threads. The Wedglok principle can be applied to screws as well.

If it's a matter of how to fasten one thing to another . . . get in touch with GKN

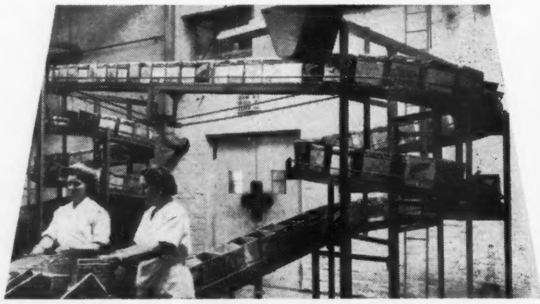
Wedglok Self-Locking Products are manufactured under licence in the United Kingdom solely by
Guest Keen & Nettlefolds (Midlands) Ltd., Screw Division, Box 24, Heath St., Birmingham 18. Tel: Smethwick 1441

S/WK/3825



the shape of things we handle

Cars, crates and cases, bottles, bags and bacon, no matter what the product is, Paterson Hughes can supply a materials handling system specially suited to fulfil the requirements of your particular needs.



Conveyor for biscuit tins at Peek Frean Ltd.

Roller conveyor for handling cartons and crates

Car assembly line at a Rootes Group Factory

MECHANICAL HANDLING ENGINEERS AND CRANE MAKERS

PATERSON HUGHES
ENGINEERING COMPANY LIMITED

PATERSON HUGHES ENGINEERING COMPANY LIMITED
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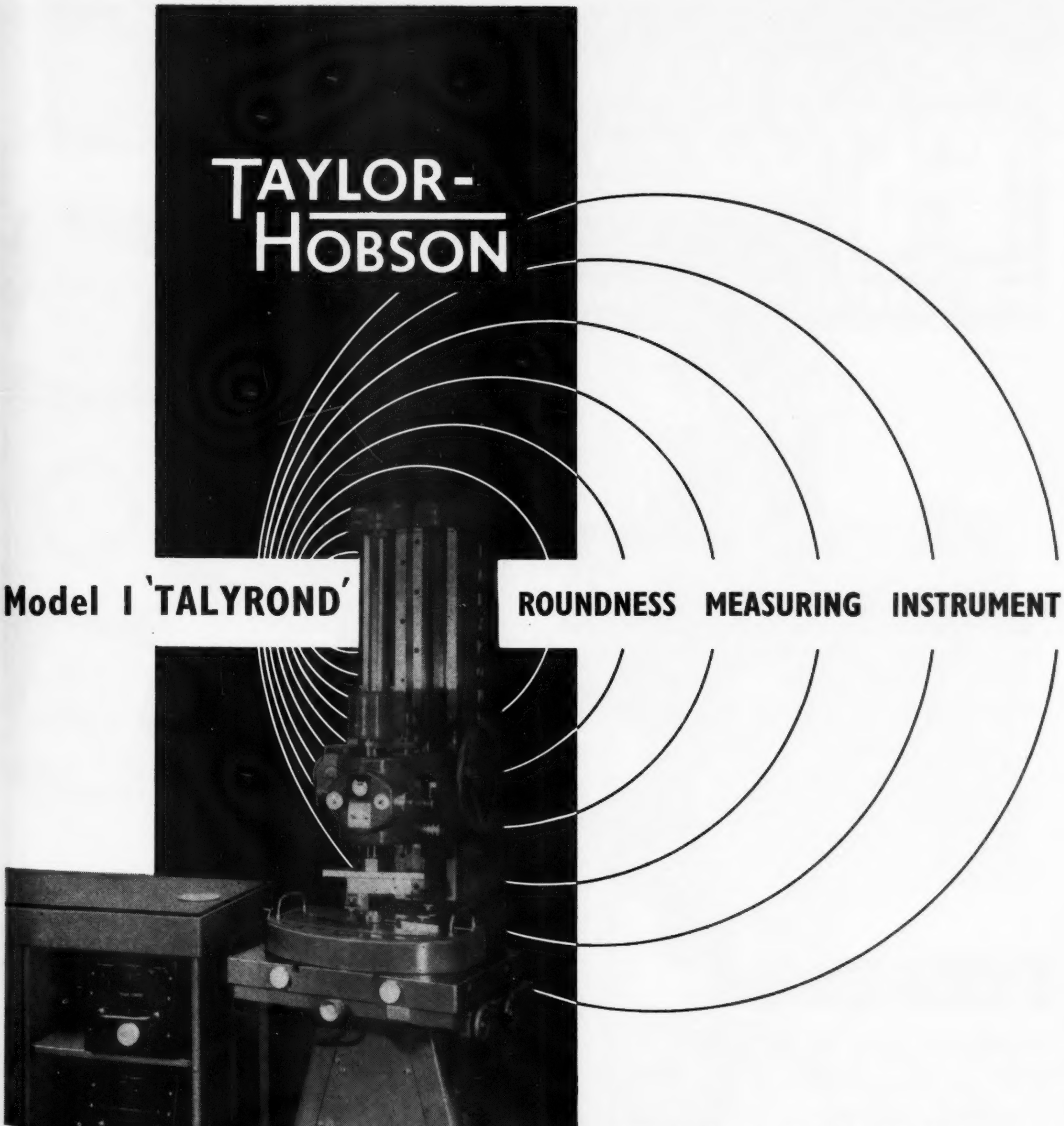


Smoother, quieter for faster running.

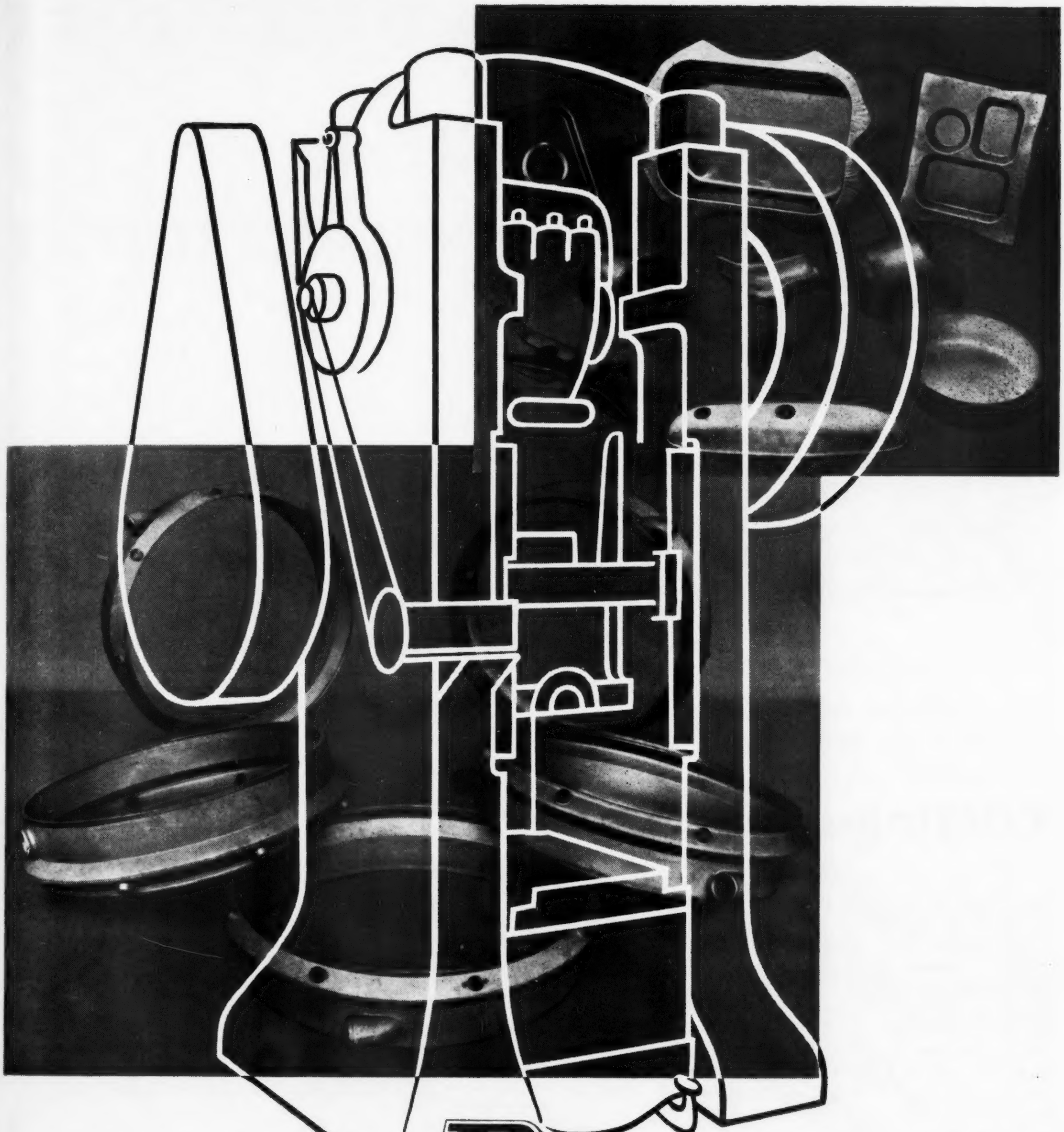
Roundness is the key to smoother, quieter faster running, and such qualities depend upon the correct geometric shape as well as dimensional accuracy.

The Taylor-Hobson 'Talyrond' Roundness Measuring Instrument will measure errors as infinitesimal as 3 micro-inches (.000,003-ins), thus assisting in the analysis of manufacturing processes, leading to optimum performance.

TAYLOR TAYLOR & HOBSON LTD.
LEICESTER · ENGLAND

A Division of
RANK PRECISION
INDUSTRIES LTD.

TRI/18



Wadkin CY.I. machine at Messrs. Crane Ltd., Ipswich, cutting-off brass bars for valve parts.


How many per minute?
Noral
28S
free cutting
aluminium alloy
Noral 28S free-cutting alloy machines even better and faster than conventional aluminium alloys! No build-up on the cutting tool, no awkward long pieces of swarf! It costs, volume for volume, little more than half as much as free-cutting brass.
How fast can you produce parts such as this television coaxial plug component? With Noral 28S it depends only on the capacity of the machine!
May we send you further details?
NORTHERN ALUMINIUM COMPANY LTD · BUSH HOUSE · ALDWYCH WC2 · TEMPLE BAR 8430 · AN ALUMINIUM LIMITED COMPANY

TBW/T16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the RICHMOND range of machine tools
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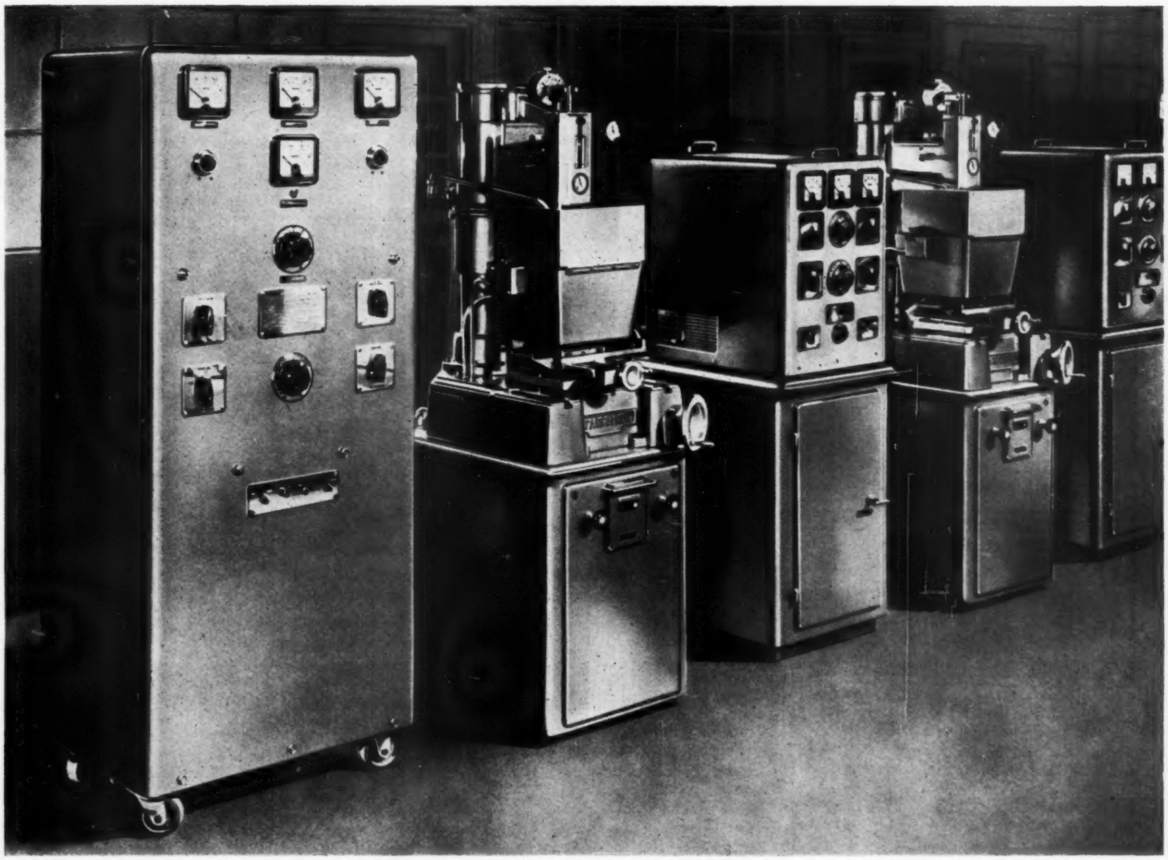
The leading manufacturers of spark machining equipment now introduce their latest

Mk III Model

6·5 KW



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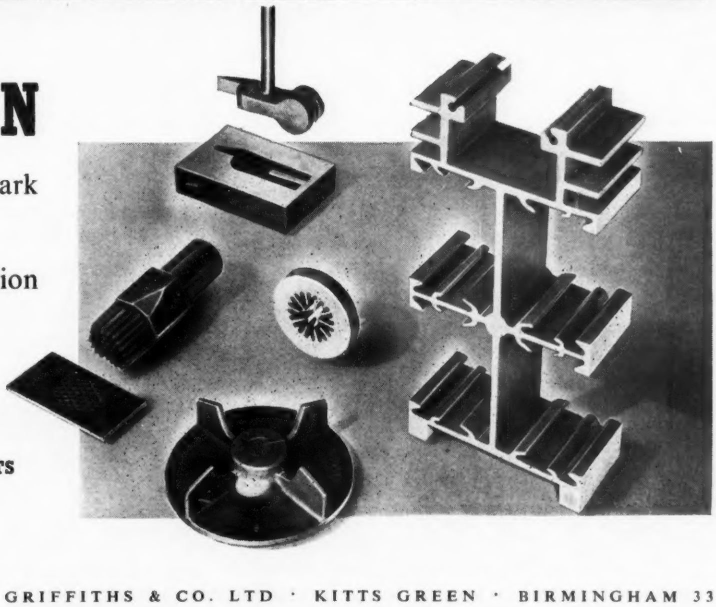

Manufactured by

IMPREGNATED DIAMOND PRODUCTS LIMITED

GLOUCESTER · ENGLAND

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